LTPP Manual for Profile Measurements
Operational Field Guidelines
Version 3.1

January 1999

Pavement Performance Division
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16. Abstract This manual describes operational procedures to be followed when measuring pavement profiles for the Long Term Pavement Performance (LTPP) Program using the K.J. Law Profilometer®, Face Technologies Dipstick®, and the rod and level. Field testing procedures, data collection procedures, calibration of equipment, record keeping and maintenance of equipment for each of the profiling methods are described.			
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Operational Field Guidelines
Version 3.1

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FOREWORD

The LTPP Manual for Profile Measurements, Operational Field Guidelines, Version 3.1, January 1999 is an update of the version 3.0 of the manual. Only specific sections and pages were updated in Version 3.1, and the updated pages have "LTPP Manual for Profile Measurements, January 1999" printed in the page header.

The following are the pages and sections that were updated in version 3.1 of the manual.

- Pages i through xv that contain Foreword, Preface, Acknowledgments, Table of Contents and List of Figures.
- Section 2: Profile measurements using the K.J. Law Profilometer®, pages 2-1 through 2-65.
- Pages 3-17 and 3-18
- Section 5: References, page 5-1.
- A new Appendix, Appendix VI, "Profile Trouble Shooting Guide" has been added to the manual.

The other portions of the manual have not been changed from the Version 3.0, and will have the "LTPP Manual for Profile Measurement, July 1997" in the page header.

PREFACE

The Long Term Pavement Performance (LTPP) program is a study of pavement performance at nearly 3,000 in-service pavement sections throughout North America. The LTPP's goal is to extend the life of highway pavements through various designs of new and rehabilitated pavement structures, using different materials and under different loads, environments, subgrade soil, and maintenance practices. The specific objectives of the LTPP program are to:

- evaluate existing design methods;
- develop improved design methods and strategies for the rehabilitation of existing pavements;
- develop improved design equations for new and reconstructed pavements;
- determine the effects on pavement distress and performance of loading, environment, material properties and variability, construction quality, and maintenance levels;
- determine the effects of specific design features on pavement performance; and
- establish a national long-term pavement performance database

LTPP will collect data on in-service pavement sections over a twenty-year period. The data collected at the test sections are stored in the LTPP Information Management System (IMS) database. These data will be used to achieve the goal and objectives of the LTPP program.

The collection of longitudinal profile data at each test section is a major task of LTPP. The left and right wheel path profile data for five repeat runs on a test section are stored in the LTPP IMS. In addition, the International Roughness Index (IRI), Mays Index, Root Mean Square Vertical Acceleration (RMSVA) and Slope Variance, which are computed from the profile data are also stored in the LTPP IMS.

This manual describes procedures to be followed when measuring pavement profiles for the LTPP program using the K.J. Law Profilometer®, Face Technologies Dipstick®, and the rod and level. Field testing procedures, data collection procedures, calibration of equipment, record keeping and maintenance of equipment for each of the profiling methods are described. The primary device used to obtain pavement profile measurements for LTPP is the K.J. Law Profilometer®. However, when a Profilometer® is not available, the Dipstick® is used to collect profile data. A rod and level can also be used to measure pavement profile if a Profilometer® or a Dipstick® is not available.

ACKNOWLEDGMENTS

Many of the operating procedures described in this manual for the K.J. Law Profilometer® were obtained from the Road Profilometer® Model T-6600 User's Manual. Some material relating to the operation of the Face Construction Technologies, Inc. Dipstick® was obtained from the Instruction Manual for the Dipstick®.

The following registered trademarks are used in this document:

- Dipstick® is a trademark of Face Construction Technologies
- Profilometer® is a trademark of K.J. Law Engineers, Inc.
- Iomega™ and Zip™ are registered trademark of Iomega Corporation

TABLE OF CONTENTS

LIST OF FIGURES

1. INTRODUCTION

1.1 OVERVIEW OF THE LTPP PROGRAM

The Strategic Highway Research Program (SHRP) was a five-year, $150 million research program which began in 1987. The research areas targeted under SHRP were: asphalt, pavement performance, concrete and structures, and highway operations. SHRP's Long Term Pavement Performance Program (LTPP) is a first ever effort to study pavement performance in different climates and soil conditions at nearly three thousand in-service pavement sections in all fifty states of the United States and in participating provinces in Canada. The LTPP program was designed as a twenty year study. The first five years of this program - 1987 to 1992 - were administrated by SHRP, and since 1992, administration of the program has been the responsibility of Federal Highway Administration (FHWA).

For purposes of pavement data collection and coordination, the United States and participating Canadian provinces have been subdivided into four regions, each served by a Regional Coordination Office (RCO). The regional boundaries defining the jurisdiction of each RCO are shown in figure 1.1.

1.2 SIGNIFICANCE OF PAVEMENT PROFILE MEASUREMENTS

The longitudinal profile along the wheel paths in a pavement can be used to evaluate the roughness of the pavement by computing a roughness index such as the International Roughness Index (IRI). The change in longitudinal pavement profile over time, which is directly related to changes in roughness with time, is an important indicator of pavement performance. Hence, one aspect of the LTPP program is to collect pavement profile data of in-service pavement sections for use in many applications such as improving pavement performance prediction.

LTPP Manual for Profile Measurement, July 1997

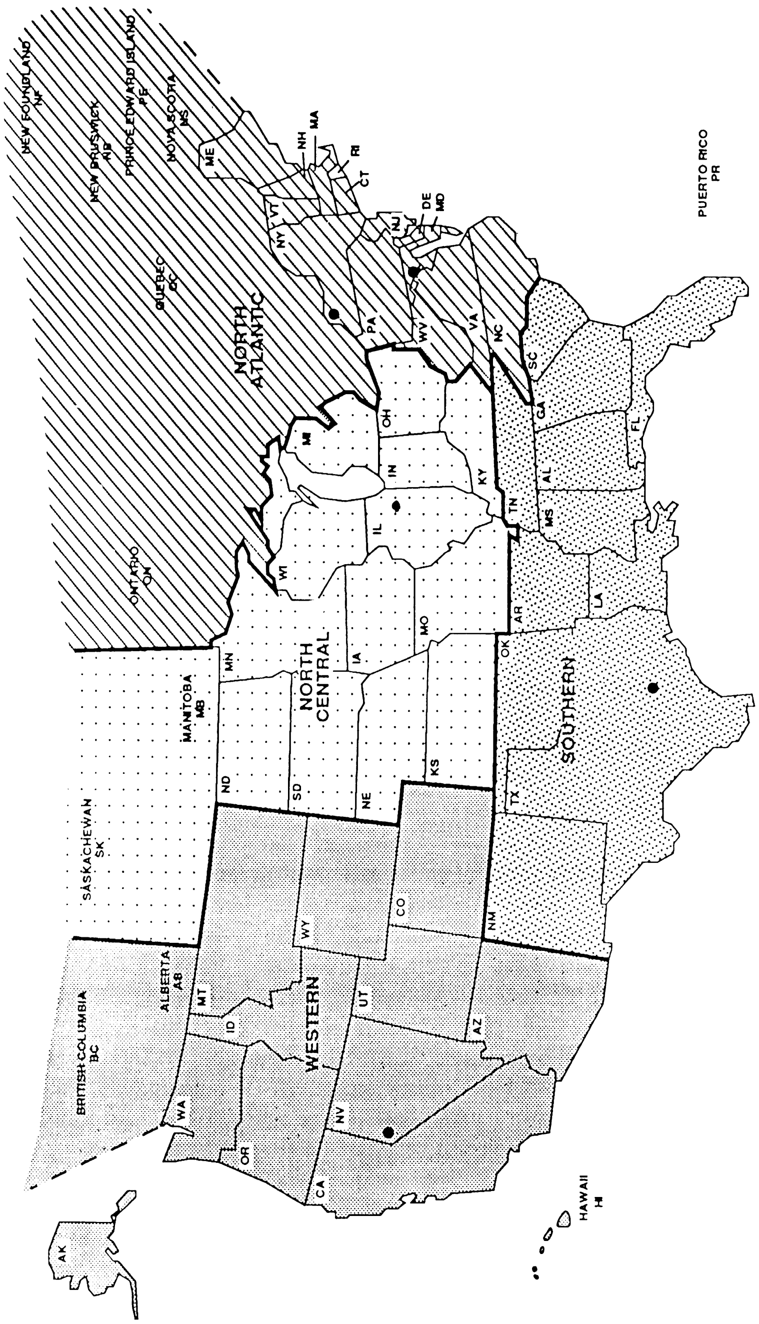

Figure 1.1 LTPP Regions

1-2

1.3 PROFILE DATA COLLECTION

The primary means used to obtain pavement profile measurements for the LTPP program is to profile test sections using a road profiler. Each RCO operates a Profilometer® to collect data within its region. From the inception of the LTPP program until the end of 1996, profile data at test sections were collected using a Model 690DNC Inertial Profilometer® manufactured by K.J. Law Engineers, Inc. In late 1996, each RCO replaced their Model 690DNC Profilometer® with a Model T-6600 Inertial Profilometer® manufactured by K.J. Law Engineers, Inc. The operation and maintenance of the Profilometer® and the storage of the collected data are the responsibility of each RCO.

When a Profilometer® is not available, LTPP has elected to use the Dipstick®, which is a hand operated digital profiler manufactured by Face Technologies, as a back-up device to collect profile data. The Dipstick® is also used to obtain transverse profile data in some circumstances. Each RCO contractor stores, maintains, and operates two Dipsticks®.

A rod and level can also be used to measure pavement profiles if a Profilometer® or a Dipstick® is not available, or where other special circumstance or requirements rule out the Dipstick® or the Profilometer®. However, this method is very labor intensive and not typically used within the LTPP program.

1.4 OVERVIEW OF THE MANUAL

This manual describes procedures to be followed when measuring pavement profiles using the K.J. Law model T-6600 Inertial Profilometer®, Face Technologies Dipstick® and rod and level. The manual covers the following:

1. Field Testing
2. Data Collection

3. Calibration of Equipment
4. Equipment Maintenance
5. Record Keeping

This document addresses those aspects of profile measurements that are relatively unique to the LTPP program. Other references [1,2,3,4,5] should be consulted for general information.

2. PROFILE MEASUREMENTS USING THE K.J. LAW PROFILOMETER

2.1 INTRODUCTION

The K.J. Law Model T-6600 Inertial Profilometer® is a modified passenger van that is equipped with specialized instruments to measure and record road profile data. The T-6600 Profilometer® contains three infrared sensors with integrated accelerometers, a longitudinal distance measuring transducer, a computer, signal conditioning electronics, and power control equipment. The front bumper of the passenger van has been removed and replaced with a structure that contains the three infrared sensors. One sensor is located at the center of the vehicle, while the other two sensors are located along each wheel path. The longitudinal distance measuring transducer is mounted in the center of the left front wheel and measures the distance traveled by the vehicle and the speed of the vehicle.

The system for measuring the road surface profile consists of the infrared displacement sensors that measure the vertical displacement between the vehicle and the road, and an integrated accelerometer in each sensor that measures vertical acceleration. Signals from the non-contact sensors, accelerometers and distance measuring system are fed into a computer which computes the profile of the pavement. Profile data are recorded at 25 mm intervals and stored on computer hard disk for further processing. During profile measurement, the road profile is displayed on the computer terminal.

The Profilometer® is equipped with two photocells. One photocell is mounted laterally to sense reflections from pre-placed cones on the side of the road, while the other photocell is mounted vertically to sense reflections from pre-placed marks on the road surface. The photocell is used to initiate profile data collection. The Profilometer® vehicle is equipped with both a heater and air-conditioning units to provide a uniform temperature for the electronic equipment in the vehicle. The Profilometer® can measure road profiles at speeds ranging from 16 to 112 km/h. The test speed is normally 80 km/h for the LTPP program.

Detailed outlines of the operating procedures, calibration, and maintenance requirements of the different Profilometer® components can be found in the manuals listed under References.

2.2 OPERATIONAL GUIDELINES

2.2.1 General LTPP Procedures

Accidents: In the event of an accident, operator will inform the RCO as soon as possible after the mishap. Details of accident should be reported in writing to the RCO. In general, the corporate policy of the RCO should be followed in event of an accident. A police report of the accident should also be obtained.

Maintenance of Records: Operator is responsible for preparing and forwarding the forms and records to the RCO as described in section 2.7, which relate to testing and maintenance of the Profilometer®.

2.2.2 Test Frequency and Priorities

The profile measurement frequency and priorities described in the latest FHWA directive should be followed when profiling LTPP General Pavement Studies (GPS), Specific Pavement Studies (SPS), Seasonal Monitoring Program (SMP) and Weigh in Motion (WIM) sites. A copy of the latest directive is included in Appendix IV; it is the RCO's responsibility to ensure that this directive be replaced with any subsequent releases.

2.2.3 General Operations

The following guidelines related to the general operation of the Profilometer® shall be followed.

2.2.3.1 Temperature Range

The interior vehicle environment is critical to the operation of the on-board computer. Fixed disks operate with very close mechanical system tolerances and may be damaged if subjected to large temperature variations or extremes. The vehicle is equipped with a heater and an air conditioner to maintain interior temperatures within the required range. The interior of the vehicle should be between 10 and 35 °C before power is applied to the electronic equipment and the computer to protect them from damage.

2.2.3.2 Disk Drives

Saving files to the hard disk or floppy disks, or loading files from the hard disk or floppy disks should not be done when the vehicle is in motion as this can destroy data files. The computer's virtual memory should be used to record all data while the vehicle is in motion.

2.2.3.3 Hardware and Software

Do not add any hardware (extra drives or any other device) to the computer system before contacting K.J. Law, through FHWA and its Technical Support Contractor (TSC) to determine if they will interfere with profile programs. Interference of profile programs due to additional devices may not be readily apparent.

The software supplied with the T6600 Profilometer® is tightly integrated. Apart from PROQUAL, other software should not be loaded on to the computer, unless specifically approved in writing by FHWA. Such software could seriously degrade the performance and accuracy of the system.

Procedures for installing the PROQUAL program are described in section 2.2 of the PROQUAL manual [6]. The installation procedure installs the PROQUAL program in the C:\PROF2 directory. PROQUAL uses the FHWACN.EXE program supplied by K.J. Law to convert the Profilometer® binary files to ASCII data before loading data to database files. In order for the PROQUAL program to operate correctly, the directory KJL_SYST which contains K.J. Law's software should be in the root directory of the C drive. The FHWACN.DAT file should also be in the KJL_SYST directory.

Profilometer® data files may be organized into subdirectories under C:\PROF2. For example, New York sites could be stored in the directory C:\PROF2\NY. All profile data files collected in New York, which include those data from GPS, SPS, SMP, and WIM sites can be placed in this directory. Alternatively, separate subdirectories may be created for the different types of sections (GPS, SPS etc.) under the directory C:\PROF2\NY.

The FHWACN.EXE program limits length of directory path in which the binary "P" files can be converted to ASCII. Any directory that has a long path (8 characters or longer) will not run through the conversion program and thus no DBF files will be created from the "P" files.

2.2.3.4 Sensor Bar and Sensor Spacing

The sensor bar located in front of the vehicle is not designed to support the weight of any personnel. Do not sit or stand on the sensor bar at any time.

The sensors located along each wheel path should be at a distance of 838 mm from the center of the vehicle. This sensor setup should result in a spacing of 1,676 mm between the left and the right sensors. The center sensor should be located such that it is 864 mm from the left sensor and 812 mm from the right sensor.

2.2.3.5 External Power Source

To use external power, plug power cord into a 120 volt source. Make sure that the external power source is grounded before connection is made. Power switches of all instruments and computer should be turned to the off position before connection is made to an external power source. The power will pass through the inverter to the system, and approximately 4 amperes of charging current will be provided to batteries. Do not leave power inverter system connected to an external power source for extended periods of time since overcharging of batteries may result. It has been reported that an electrical leak has been detected in the front bumper of the vehicle when connected to an external power source. The operator should exercise caution when working near the sensor bar (e.g., during calibration) as this condition can cause an electrical shock.

2.2.3.6 Tire Pressure

The inflation pressure of the front tires in the vehicle when it is used for testing should be between 413 and 448 kPa (60 and 65 psi). Before testing a test section, the operator should adjust the tire pressure of the front tires to ensure that the inflation pressure is between 413 and 448 kPa (60 and 65 psi).

2.2.3.7 Major Repairs to Profile System Components

The LTPP Major Maintenance / Repair Activity Report should be filled whenever repairs are performed on the profile system components such as the displacement sensor, accelerometer, distance measuring system, and data acquisition system. The displacement sensors, accelerometers, and the distance measuring system should be calibrated after such repairs are performed.

After performing a major repair, the data collected by the Profilometer® should be checked by using the following procedure to ensure that accurate data is being collected. In this procedure a test section that has been profiled previously is re-profiled, and a comparison is made between the profile data.

1. Select a test section that had been profiled recently, and is close to the current location of the Profilometer®. When selecting the site, review comments that were made when

this site was profiled to make sure that profile data available at this site is free of errors and that no unexplained spikes are present in the data. It is recommended that GPS-3 and SPS-2 sites be avoided as significant variations in profile can occur on these sections due to temperature effects.

2. Profile the selected site and obtain an acceptable set of runs as described in section 2.2.5.
3. Compare the collected data with previous data for the site. If a sensor or accelerometer has been repaired or replaced, compare the IRI values as well as the profile data for that sensor. If the repaired or replaced sensor is the center sensor, only the comparison of the profiles can be performed as IRI values for the center sensor are not available.
4. If the comparison indicates that the collected data is comparable with the previously collected data, the profile system components are considered to be functioning correctly. If discrepancies are noted, the comparison should be performed at another section. If discrepancies are still noted, K.J. Law Engineer's Inc. should be contacted to resolve the problem.

If a malfunction is detected in a sensor located along a wheel path, it may be replaced by center sensor to continue data collection. The procedure for replacing the sensor is included in Appendix V. The displacement sensor and the accelerometer should be calibrated after the sensor is moved. A comment should be made in the Field Activity Report (see Appendix I) that the center sensor was not functioning. The malfunctioning sensor should be repaired or replaced as soon as possible. Once the repaired or replacement sensor is available, the center sensor which is now located at an outer position (left or right wheel path) should be moved back to the center position. The repaired or replaced sensor should be installed at the location of the defective sensor (either left or right wheel path). The center sensor as well as the repaired/replaced sensor should then be calibrated (displacement sensor and accelerometer). The procedures that were described previously should be followed to ensure that the repaired/replaced sensor is functioning correctly.

2.2.3.8 Sensor Covers

The three sensors in the profiler are equipped with covers. The lower covers of the sensor should be taken off when performing calibration of sensors, during daily calibration check and bounce test, and when collecting profile data. The covers should be in-place when testing is not being performed to protect the sensors.

2.2.3.9 Data From Previous Profile Visit

After collecting profile data at a site, profiler operator is required to compare the profile data as well as the IRI with the data collected during the previous site visit as described in Section 2.2.5.2. The profile data comparison between the visits is made using the multi-year plot comparison option in PROFSCAN. Prior to setting out to profile a site, operator must ensure that the data files that are required to do this comparison for the previous site visit are available. The operator should also have the IRI values for the site from the previous visits.

2.2.4 Field Operations

2.2.4.1 Turnarounds

Applicable laws in each state regarding use of median turnarounds must be followed.

2.2.4.2 Flashing Signal Bar and Signs

The flashing signal bar on the Profilometer® should be used during testing. In addition, the sign "Caution Road Test" should be mounted at the back of the vehicle.

2.2.4.3 File Naming Convention

The file naming convention to be used in specifying name of data file in the Run Identification Menu (see section 2.3.5.2) is described in this section. Failure to adhere to this file naming convention could produce errors and may even lock-up the computer when running PROQUAL.

The file name should consist of eight characters as follows:

1. Characters one and two: State code of state in which site is located (e.g., 27 for Minnesota).
2. Characters three to six: Four digit site number. For GPS, SMP and WIM sites this is the four digit LTPP identification number (e.g., 1023). For SPS sites, the third character should be 0, A, B, etc., depending on project code (e.g., 0300, A300, B300, etc.). The fourth character for SPS sites is the experiment number (e.g., 2 for SPS-2 projects), while the fifth and sixth characters should always be zero.
3. Character seven: Letter code defining section type, G for GPS, S for SPS, W for WIM, M for SMP or C for Calibration test sections.
4. Character eight: Sequential visit identifier code indicating the number of times a set of profile runs has been collected at a site using the T6600 profiler. The letter “A” shall be used the first time a set of runs is collected at a site, “B” for the second time, “C” for the third time and so on. For rigid pavement test sections in the seasonal monitoring program, a different character shall be used each time a set of profiles is obtained during the day. If a region has been using the sequential visit identifier to indicate the number of times a set of profiles has been obtained at the site since its inception into the LTPP program, that procedure is also acceptable. In such case, the letter “A” shall be used to denote the first time the site was/is profiled by the RCOC, whether with the DNC690 or T6600 profiler. Thereafter, this letter shall be sequentially increased (“B”, “C”, and so on) during subsequent profile data collection visits.

The following are examples of valid data file names:

1. 171002GA: GPS section 1002 in Illinois (state code = 17), profiled for the first time.
2. 260200SB: SPS-2 site in Michigan (state code = 26), profiled for the second time.
3. 271018MB: Seasonal monitoring site 1018 in Minnesota (state code = 27), profiled

for second time.

4. 270300SA and 27A300SA: SPS-3 sites having project codes 0 and A in Minnesota (state code = 27), profiled for the first time

In cases where a GPS site and a WIM site are profiled in the same run, the letter “X” should be used for seventh character instead of a “G” (e.g., 511023XA). When this file is subdivided in PROQUAL, the data file name for the GPS site should be 511023GA while that for the WIM site should be 511023WA.

If a long SPS project is not profiled continuously, but profiled in groups of sections, the sixth character in file name should be replaced by a character for each group. For example, consider SPS-2 project in state 26 that is profiled as two groups of sections. The file name for the first group could be 26020ASA, while that for the second group could be 26020BSA.

The first two digits of the file name for a section must be valid state codes when generating file names for demonstration purposes or comparative studies. PROQUAL will not operate on data files that do not follow this convention.

2.2.4.4 Operating Speed

A constant vehicle speed of 80 km/h should be maintained during a profile measurement run. If maximum constant speed attainable is less than 80 km/h due to either traffic congestion, or safety constraints, then a lower speed depending on prevailing conditions should be selected. If speed limit at site is less than 80 km/h, the site should be profiled at posted speed limit. If site is relatively flat, cruise control should be used to maintain a uniform speed. It is important to avoid changes in speed during a profile run which may jerk the vehicle or cause it to pitch on its suspension. Change in throttle pressure or use of brakes to correct vehicle speed should be applied slowly and smoothly.

2.2.4.5 Event Initiation

During profile data collection, the Profilometer® data collection program uses "event marks" to initiate data acquisition. Event marks are generated by the photocell event detector. The vertical photocell that detects the white paint stripe at beginning of the test section should be used to initiate data acquisition. In those instances where existing paint mark on pavement is not able to trigger photocell, the lateral photocell should be used. A cone with the reflective marker or an FHWA approved device should be placed on the shoulder at the beginning of the test section to initiate the lateral photocell. The photocell event detector shall be the only run control initiation method used in all profiling operations. The pendant shall not be used for initiation of profiling operations.

2.2.4.6 Recording Profile Data

The computer virtual memory will be used as the recording medium during profile runs. After a run is completed, the driver should pull over to a safe location and come to a complete stop so that data can be transferred to the hard disk prior to another profile run. On sections where the turn around distance is relatively short, operator can complete all runs before saving data to the hard disk. All data should be transferred to the hard disk and a backup copy of these data made to Iomega Zip™ disk (section 2.2.4.8) before leaving test section.

2.2.4.7 Inclement Weather and Other Interference

Inclement weather conditions (rain, snow, heavy cross winds) can interfere with the acquisition of acceptable Profilometer® data. Profile measurements should only be performed on dry pavements. In some cases, it may be possible to perform measurements on a damp pavement with no visible accumulation of surface water. Under such circumstances, the data should be monitored closely for run to run variations and potential data "spikes". The PROFSCAN program[6] should be used to detect spikes. This program uses a threshold value of 2.5 mm to identify spikes. Spikes can occur due to field related anomalies (e.g., potholes, transverse cracks, bumps) or due to electronic conditions or interference.

Changing reflectivity on a drying pavement due to differences in brightness of pavement (light and dark areas) may yield results inconsistent with data collected on uniformly colored (dry) pavements. Run to run variations in data collected under such conditions should be carefully evaluated. If problems are suspected, profile measurements should be suspended until pavement is completely dry.

Electromagnetic radiation from radar or radio transmitters may interfere with Profilometer® operations and data recording. If this occurs, operator should attempt to identify and to contact the source to learn if a time will be available when the source is turned off. If such a time is not available, it may be necessary to schedule a Dipstick® survey of the test section.

2.2.4.8 Data Backup

The profile data should be backed up to an Iomega Zip™ disk. All profile data is to be backed up to a Zip™ disk using the Iomega Zip™ disk drive from the computer immediately after testing is completed at a section. The operator should maintain a log for each Zip™ disk to document the files that are in the Zip™ disk. The Profilometer® should not leave a test site unless all data has been backed up. At the end of each day, an additional backup copy of all Profilometer® test data collected on that day should be made on a Zip™ disk. Therefore, at the end of each test day, there would be two Zip™ disks that contain the profile data that were collected on that day. One of this disks should be kept in the Profilometer® (Profilometer copy) while the other copy (RCO copy) should be forwarded to the RCO. Until the RCO copy is forwarded, the Profilometer copy must be removed from the vehicle whenever testing is not in progress. No collected profile data should be deleted from the hard disk until the RCO has informed the operator that the RCO copy has been received and processed by the RCO. The Profilometer copy of the Zip™ disk can be recycled once the RCO informs the operator that the data has been received, processed and backed up. The RCO should backup the data following the procedures outlined in the latest FHWA directive.

The operator should maintain a copy of the K.J. Law software and the Proqual software in the vehicle in case software problems occur in the software installed in the computer.

2.2.4.9 End of Run and Operator Comments

The K.J. Law software allows the operator to enter comments at the end of each profile run; those comments are hereafter referred to as “end of run” comments. Operators can also enter comments about the profiled site after the PROFSCAN software is run; those comments are referred to as “operator” comments. Both sets of comments can be up to 55 characters in length and they are uploaded into the LTPP database or IMS.

The end of run comments entered for a group of sections profiled in one run (e.g., SPS site) are put into each individual file that is subsectioned from that profile run. Similarly, if a GPS section is profiled in conjunction with a SPS site in one run, end of run comments are common to all sections subsectioned from that profile run. Therefore, the operator should ensure the end of run comments that are entered when several test sections are profiled in one run are valid or applicable to all sections in that run (e.g. a weather related comment). In this section, examples are provided separately for end of run comments and operator comments with the suggested format for the comment.

End of Run Comments

As described previously, an end of run comment that is made when a group of sections are profiled together is put into all profiles that are subsectioned. Therefore, an end of run comment that is made in such cases should be common to all the sections that were profiled in one run. To ensure uniformity between the end of run comments that are made when a group of sections that are profiled together (e.g. SPS section) and when a section is profiled as an individual section (e.g. GPS section), end of run comments have been grouped into the following three categories:

1. Good Profile Run

   Comment used to indicate that profile run was good and that no problems were encountered.

   Example comment: Run OK.

2. Environmental Related Comments

   Profile testing should not be performed when environmental conditions are so bad that they can affect the quality of the data. If the operator believes there is a possibility that the environmental conditions may have affected the quality of the data a comment should be entered. An example of such a condition is a windy day.

   Example comment: Heavy winds.

3. Speed Related Comments

   The following are examples where a comment related to the speed of testing should be entered:

   (a) Speed limit at site is lower than 80 km/h specified for profile data collection.

   Example comment: Speed limit at site is 60 km/h.

   (b) Heavy traffic, difficult to maintain a constant speed.

   Example comment: Difficult to maintain constant speed, heavy traffic

   (c) Difficult to maintain constant speed because of grade (uphill or downhill).

   Example comment: Difficult to maintain constant speed, uphill.

Operator Comments

Operator comments are entered when PROFSCAN is run. They can fall into one of the following six categories:

1. Pavement Distress Related Comment

   A comment should be made if there are pavement distresses or features within the section that can affect the repeatability of profile data. The comment should specify the distress(es) present which the operator believes to be causing the non-repeatability of profile data. The following are examples where such comments may be entered:

   (a) For asphalt concrete pavements distresses such as rutting, fatigue/ alligator cracking, potholes, patches, longitudinal and transverse cracking.
   Example comment: __________ in section (enter distress type for blank).

   (b) For concrete pavements distresses such as faulting, spalling, longitudinal and transverse cracking.
   Example comment: __________ in section (enter distress type for blank)

   (c) For pavements with a chip seal, a comment should be entered if chips are missing in areas within the section.
   Example comment: Chip seal section, chips missing

   (d) Comment should be made if there are dips within the section.
   Example comment: Dips in section.

2. Maintenance Related Comments

   A comment should be made if operator is familiar with the test section and notes that recent maintenance and/or rehabilitation activities (e.g., overlays, patches, crack filling or aggregate seals) have been performed on that section. The operator should specifically make a note if overband type crack filling has been performed on the section.

Example comment: Recent maintenance in section, patches.

3. Wheel Path Tracking Related Comments

   A comment should be entered if operator encountered problems in tracking the wheel path. Such comment should be entered if one or more of the following conditions are encountered:

   (a) During profile run, path followed was either to the left or to the right of wheel path.

   Example comment: Run right of wheel path.

   (b) Difficulty in holding wheel path due to pavement distress(es) such as rutting.

   Example comment: Difficult to hold wheel path, rutting.

   (c) Difficulty in holding wheel path due to truck traffic.

   Example comment: Difficult to hold wheel path, traffic.

   (d) Difficulty in holding wheel path due to wind.

   Example comment: Difficult to hold wheel path, windy.

   (e) Difficulty in holding wheel path because of grade, either uphill or downhill.

   Example comment: Difficult to hold wheel path, uphill.

   (f) Difficulty in holding wheel path because section is on a curve.

   Example comment: Difficult to hold wheel path, curve.

4. Location of Test Section Comments

   A comment should be entered if the location of the section has a potential impact in obtaining repeatable profile runs. Such conditions include:

(a) Section or approach to section is on a curve.
Example comment: Approach to section on curve.

(b) Section or approach to section is on a grade (uphill or downhill).
Example comment: Section on a downhill.

5. Miscellaneous Other Comments
A comment should be entered if conditions other than those not covered previously are encountered during profiling that may affect the quality of the data. Such conditions include:

(a) Contaminants on road such as sand/gravel or dead animals.
Example comment: Sand on road.

(b) Traffic or weigh in motion (WIM) loops within test section.
Example comment: WIM loops within section or Traffic loops in section.

(c) Color variability of the pavement because of salt application.
Example comment: Color variability caused by salt.

(d) Excessive vehicle movements just prior to test section because of pavement condition.
Example comment: Core holes on wheel path before section.

6. Spike Related Comments
After the PROFSCAN program is run, the operator should look for the presence of spikes in the data. If present, enter comment indicating whether or not the spikes are pavement related -- comment is entered in PROFSCAN.

Example comment: Pavement related spikes in profile.

As indicated earlier, the end of run comments can be up to 55 characters in length. If no problems were encountered during the run, the comment “Run OK” should always be entered as an end of run comment. If there were weather/environmental related comments, or speed related comments these should be entered following the guidelines that were presented previously.

Operator comments can also be up to 55 characters in length. If spikes are observed in the profile, it is mandatory for the operator to enter a comment regarding these spikes after running the PROFSCAN program indicating whether or not they are pavement related. Because of the 55 character constraint, it may not be possible to type in all of the applicable factors from the list of factors that were described previously. Therefore, when entering comments, it is recommended that the following order of priority (with the first factor listed being given the highest priority) be followed: Wheel Path Tracking Related Comments, Pavement Distress Related Comments, Maintenance Related Comments, Miscellaneous Other Comments and Location of Test Section Comments. It should be noted that the comments are used to indicate factors that could affect the quality of data or to indicate factors that cause variability between profile runs. Depending on the conditions encountered in the field, the recommended priority order may be changed with the factor having the greatest effect on quality or repeatability of profile data being listed first. If there are factors that cannot be entered because of space constraints, such factors should be entered in the LTPP Profilometer Field Activity Report (under the field Additional Remarks Regarding Testing). (Note: if a factor has been entered as an operator comment into PROFSCAN, it should not be repeated in the Field Activity Report).

2.2.5 Number of Runs

This section describes the procedures to be followed to obtain an acceptable set of profile data at a site.

2.2.5.1 Obtaining an Acceptable Set of Runs

During each run, the computer terminal displays the profile of the left and the right wheel paths; however, IRI values are not displayed at the end of the run. After obtaining five profiler runs, the operator should select the “Off Line Menu Option” from the main menu. Once this option is selected, the following menu is displayed (directory C:\PROFILES is used as an example):

A> CURRENT DIRECTORY C:\PROFILES
B> RUN PROFILE HEADER EDITOR
C> DISPLAY DATA
D> PRINT CALIBRATION ARCHIVE FILE
E> PRINT FIELD ACTIVITY REPORT
F> PRINT FIELD ACTIVITY REPORT SPS
G> SPIKE DETECTION PROGRAM
H> PROFILE GRAPHICAL COMPARE PROGRAM
I> IRI COMPARE PROGRAM
J> PROFILE PARSE PROGRAM
K> BACKUP PROFILES PROGRAM

X> EXIT TO MAIN MENU

Operator can use the “Display Data” option in this menu to view and print the recorded data. The “IRI Compare Program” option may be used to compute the IRI values of the profiler runs. The following procedures should be followed to perform these tasks.

<u>View and Print Profile Data</u>

Data recorded by the left, right and center sensors for one profiler run should be printed using either the “Display Data” option from the above menu, or PROQUAL program. For each profile run, the left, right and center profiles should be visually compared. If there is a malfunction in the center sensor, this will be seen from comparison of the three profiles.

It is important that this comparison be made, as it is the only quality assurance check that is performed on data collected by the center sensor.

Compute IRI Values

The "IRI Compare Program" option may be used to obtain IRI values of the five runs. IRI values will provide the operator with an indication of the run to run variability that is present at the site. The degree of run to run variability in IRI within a section, under normal operating conditions, will usually depend on the pavement roughness. On new asphalt concrete overlays or new portland cement concrete pavements, IRI variation between runs will be small. Alternatively, rough pavements will generally cause larger variability in IRI between runs.

Once the operator is confident that a minimum of five error free runs have been obtained, acceptability of the profile runs based on LTPP criteria has to be evaluated using the PROFSCAN program. (6) This procedure is described in section 2.2.5.2.

2.2.5.2 IRI from PROFSCAN

After the operator obtains five runs at a site, the PROFSCAN program should be used to determine if they satisfy the LTPP criteria. This program is one of several in the suite of PROQUAL programs. Procedures for running the PROFSCAN program are described in Section 3.1 of the PROQUAL manual. (6)

Figure 2.1 shows the parameter screen of the PROQUAL program. **Operator should ensure that the parameter settings described below are shown on the screen.**

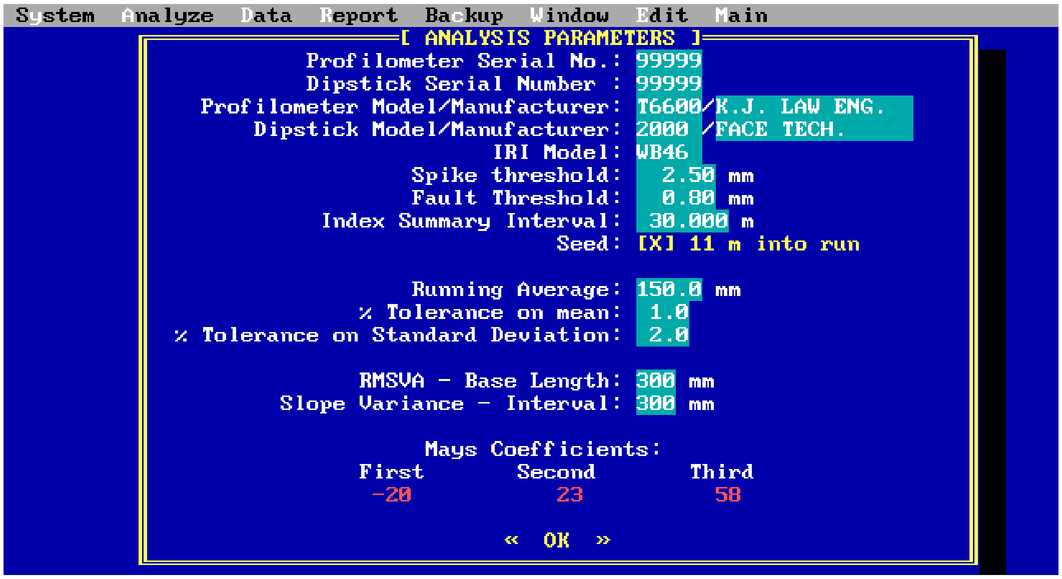

Figure 2.1 Parameter Screen in Profscan

Profilometer® Serial No: Last five digits of Profilometer® vehicle identification number.

Dipstick Serial Number: Not applicable; set to 99999.

Profilometer Model/Manufacturer: Model should be T6600 and manufacturer K.J. LAW ENG.

Dipstick Model/Manufacturer: Not applicable; can be left at default value shown in Figure 2.1.

IRI Model: Should indicate WB46.

Spike Threshold Value: Value should be 2.50.

Fault Threshold: Value not used in computations, set to 0.80.

Index Summary Interval: Summary interval at which IRI is displayed when IRI values are computed; set to 30 m.

Seed: Specify “X” in box.

Running Average: Set to 150.0 mm.

% Tolerance on Mean: Set to 1.0.

% Tolerance of Standard Deviation: Set to 2.0.

RMSVA - Base Length: Value not used in computations; set to 300 mm.

Slope Variance - Interval: Value not used in computations; set to 300 mm.

Mays Coefficients: Set coefficients to the following values: first - 20, second - 23, and third 58, respectively. These coefficients are used to compute Mays Output in the PROQUAL program.

The PROFSCAN program uses collected profile data to compute IRI values for both the left and right wheel paths, as well as the average IRI of the two wheel paths. The PROFSCAN program also generates a report of spikes present in the pavement profile. Profilometer® runs at a site are accepted if the average IRI of the left and right wheel paths satisfies the following LTPP criteria:

1. IRI of three runs are within 1% of mean IRI of selected runs.
2. Standard deviation of IRI of selected runs is within 2% of mean IRI.

If PROFSCAN indicates that the five runs are not acceptable, the procedures described in Section 2.2.5.3 should be followed.

If PROFSCAN indicates that the five runs are acceptable, but spikes are present in the data, operator should determine if they are pavement related or the result of equipment or operator error. Operator should examine plots of all profile runs for discrepancies and features that cannot be explained by observed pavement features, and also study the spike reports. Operator should use the multi-run plot in PROQUAL to do this comparison (see Section 3.3.5 of PROQUAL Manual). If there are spikes believed to be caused by operator or equipment error, operator should correct cause of the anomalies and make additional runs until five runs free of equipment or operator errors are obtained.

As a further check on the data, the operator should compare the current profile data with those obtained during previous site visit. Operator should also be familiar with the trouble shooting guide included in Appendix VI. The material presented in this appendix describes common errors that occur during profiling and is a valuable tool in identifying problems when profiles are being compared.

As specified in Section 2.2.3.9, operator must have profile data for site from previous site visit. The comparison between current profile data and those from the previous visit should be performed using the multi-year plot comparison option in the PROFSCAN software (section 3.3.5 of PROQUAL Manual). This comparison should be performed separately for the left and right wheel paths. Operator should select a minimum of one profile run from the current set of profile runs and compare it with one profile run collected during previous site visit. If differences are observed between those two profile runs, further comparisons should be made using the remaining runs from both the current and previous visit. If there are still discrepancies between the runs, operator should verify that these differences are not caused by equipment problems or due to incorrect subsectioning in SPS test sections. Operator should also explore if the differences are due to pavement maintenance activities on the test section.

After the profile comparison is completed, an IRI comparison of current versus previous site visit data should be performed using procedures described in Section 2.2.5.4.

If IRI from Profilometer® runs meet LTPP criteria in the PROFSCAN software and operator finds no other indication of errors, no further testing is needed at that site. If PROFSCAN indicates that the five runs do not meet the established criteria, follow the procedures described in Section 2.2.5.3.

2.2.5.3 Non-Acceptance of Runs by PROFSCAN

Profiler operator is responsible for carefully reviewing profile data to determine if a high degree of run-to-run variability is indicative of "bad" data or indicative of a pavement with a high degree of transverse variability. If runs do not meet LTPP criteria, operator should perform the following steps to determine if variability is the result of equipment/ operator errors, environmental effects, or pavement related.

1. Review end of run comments and assess the following factors to determine if any of them could have affected the collected data: passing trucks, high winds, rapid acceleration or deceleration of vehicle.

2. Review spike report generated by PROFSCAN to determine if spikes are the result of field related anomalies (e.g., potholes, transverse cracks, bumps) or due to electronic failure or interference. This can be determined by reviewing the PROFSCAN reports and observing if spikes occur at the same location in all runs. Operator should also examine all profile plots for discrepancies and features that cannot be explained by observed pavement features. PROFSCAN provides the user with the capability to compare multi-run plots (Section 3.3.5 of PROQUAL Manual). This feature should be used to compare data between runs when analyzing differences between profiler runs.

3. Compare current profile data with those collected during previous site visit. This comparison can be performed using the multi-year plots option in the PROFSCAN software (Section 3.3.5 of PROQUAL Manual). This comparison may indicate potential equipment problems.

If variability between runs or spikes are believed to be operator related or equipment error, identify and correct cause(s) of anomalies and make additional runs until a minimum of five runs free of equipment or operator errors are obtained.

Where data anomalies are believed to be caused by pavement features, rather than errors, a total of seven runs should be obtained at that section and evaluated using the PROFSCAN software. If data from last two runs are consistent with those from first five runs in terms of variability and presence of pavement-related anomalies, no further runs are required. If data from last two runs differ from those for first five runs, operator should re-evaluate cause of variability or apparent spike condition. If no errors are found, obtain two additional runs and terminate data collection at that section.

Thereafter, the IRI values along the left and the right wheel paths should be compared with the IRI values obtained during the previous test section visit as described in Section 2.2.5.4.

2.2.5.4 Comparison of IRI with Previous Values

The operator should have the IRI values obtained along the left and the right wheel path for the previous profile test dates for all test sections. Once the operator obtains an acceptable set of runs at a test section, the IRI values along the left and the right wheel paths should be compared with the IRI values that were obtained for the previous test date for the section. The operator should determine if the current IRI value along either the left or the right wheel path is higher or lower than 10 percent of the IRI value at the test section from the previous test date. If the difference in IRI is greater than 10 percent, the operator should see if the cause for the change in IRI could be related to a pavement feature (e.g. maintenance activity, cracks or patches along wheel path). If the cause for the change can be observed, it should be noted in the comments field in PROFSCAN.

2.3 FIELD TESTING

2.3.1 General Background

The procedures to be followed each day prior to and during data collection with respect to daily checks of vehicle and equipment, start-up procedures, setting up software for data collection and using software for field data collection are described in the following sections.

The following sections will describe the procedures to be followed when testing General Pavement Studies (GPS) sections. Some of the procedures to be followed for testing Specific Pavement Studies (SPS) sections are different than the procedures for GPS sections. section 2.4 of this manual outlines the procedures for SPS sections which differ from those for GPS sections.

2.3.2 Daily Checks on Vehicle and Equipment

Operator should follow the "Daily Check List" form given in Appendix I and perform all checks outlined at the start of day. It is not necessary to fill in this form. This form can be placed inside a plastic cover, and operator can go through items listed and make sure that everything is in proper working condition. Operator should maintain a log book in the Profilometer® to note any problems when going through the checklist. The suggested format of the logbook is included in Appendix I.

2.3.3 Setting Up the Software

In order to maintain the computer and various associated equipment, care must be taken to either cool or warm the equipment to the operating temperature described in section 2.2.3.1 prior to turning on the power. Electronic equipment in the Profilometer® should be turned on for about 30 minutes prior to testing in order for the electronics to stabilize.

The MS-DOS commands “Date” and “Time” should be placed in the AUTOEXEC.BAT file so that when the computer is turned on it will prompt operator for date and time. This will ensure that data files have the correct date and time stamp. The time should correspond to that of the time zone where the section is located. When the computer prompts for date and time, operator should check if current values are correct. If they are correct, operator can press the “Enter” key at each prompt. If they are incorrect, correct values should be entered. When system boots up, it will display the following main menu.

A> RUN PROFILE
B> CALIBRATION
C> DIAGNOSTICS
D> DISK UTILITIES
E> DISPLAY DATA
F> CONVERT PROFILE
G> OFF LINE MENU

X> EXIT TO DOS

Enter LETTER or Position And Press Enter - Press X to EXIT

2.3.4 Calibration Checks

The following calibration checks should be performed daily before profile measurements are taken.

1. Displacement Sensor Check
2. Bounce Test

The power to the electronic equipment should be turned on for about 20 minutes prior to performing either of these two tests so that the electronic equipment would warm up and stabilize.

2.3.4.1 Displacement Sensor Check

The displacement sensor check should be performed every day prior to data collection. This check is a test of the displacement sensors to determine if they are within tolerance. The check should be carried out in an enclosed building or at a location where the vehicle is protected from wind. Alternatively, the vehicle can be parked on the side of a building to protect it from wind during this check. It is recommended that this test be performed at a shaded location as it has been noted that sunlight could cause some interference with the readings. The vehicle should also be parked on a level surface with the engine turned off when performing this test. A hand-level placed on the sensor bar can be used to verify that the sensor bar is level when this test is performed. The sensors should be cleaned prior to performing this test. Operator should adjust computer monitor so that it can be seen from outside the vehicle, and the keyboard should be placed on the floor of the van. Do not enter, bounce or bump vehicle, or lean on vehicle when this check is performed. To begin the calibration check, select “Calibration” from the main menu. The following calibration menu will then be displayed:

A> CALIBRATE IR SENSORS
B> DISPLAY IR SENSORS

C> CALIBRATE ACCELEROMETER
D> DISPLAY ACCELEROMETERS

E> CALIBRATE WHEEL PULSE ENCODER

F> ENTER CALIBRATION VALUES
G> STORE CALIBRATION VALUES
H> PRINT CALIBRATION VALUES

I> DISK UTILITIES
J> HELP
X> EXIT

Enter Letter Or Position and Press Enter - Press X to EXIT

The following procedure should be used to check calibration of the sensors.

1. Follow steps 1 through 6 described in section 2.5.2 of this manual.
2. Follow step 7 described in section 2.5.5 of this manual and press the "F1" key to obtain height of block. If height of block displayed on screen is within ± 0.25 mm of 25 mm (which is height of block), sensor has passed calibration check. Then press the "ESC" key and the software will prompt user if he/she wants to leave the calibration program. A "Yes" answer followed by the "ESC" key will take user out of the calibration program.

   If height of block displayed is outside tolerance of ± 0.25 mm, then exit Calibration Program as described, and repeat calibration check five times and compute the average height and check if the average height is within tolerance. If tolerance cannot be achieved, move the vehicle to another location and repeat the calibration check. If the tolerance cannot be achieved, the operator should calibrate the sensors following the procedures outlined in section 2.5.2, and save the calibration factors.
3. Perform calibration check for other two sensors following the approach as described in steps 1 and 2.
4. If a sensor fails the calibration check and has to be calibrated, the operator should re-evaluate profile data that was collected during the previous day. If the re- calibrated sensor was in either the left or the right wheel path, the IRI values obtained should be compared with IRI values obtained from previous profile dates. If data problems are suspected, such sections should be re-profiled.

2.3.4.2 Bounce Test

The bounce test should be performed every day prior to data collection; vehicle engine should be turned off while performing test. The profile generated during this test (when vehicle is "bounced") is recorded. If the IRI value (average of left and right wheel path IRI) is less than 0.10 m/km, both sensors are considered to be functioning properly.

Printouts of the left and right sensor profiles are also generated and visually compared to that for the center sensor in order to verify that the center sensor is functioning properly.

Because pavement surface texture can affect the IRI values obtained from the bounce test, operator may place a smooth rubber mat or other such standard surface below the sensors when performing the bounce test.

The specific procedure for conducting the bounce test is as follows:

1. Take covers off the sensors and wipe sensors carefully with a cloth to clean them.
2. Select “Run Profile” from Main Menu.
3. Select “System Setup” from “Run Profile Menu” (see Section 2.3.5). Change “Graphics Scale” to 3.12 mm in System Setup (see Section 2.3.5.1) by toggling the “Enter” key. Then, select “Test Mode Oscillator” and toggle the “Enter” key so that it is enabled. Exit menu to go back to Run Profile Menu.
4. Select “Run Identification” from Run Profile Menu (see Section 2.3.5). Select “Output File Name” from Run Profile Menu (see Section 2.3.5.2) and type a file name. Exit menu to go back to Run Profile Menu.
5. Select “Run Control” from Run Profile Menu (see Section 2.3.5). Select “Start Record Method” from the Run Control Menu (Section 2.3.5.5) and toggle the “Enter” key so that the Start Record Method is “pendant.” Next, select “Stop Record Method” and toggle the “Enter” key so that the Stop Record Method is “distance.” Set Stop Record Distance to 300 m. Exit menu and go back to Run Profile Menu.
6. Select “Options Setup” from Run Profile Menu (see Section 2.3.5). In Options Setup Menu (see Section 2.3.5.6), set Profile Index Type to “IRI”, Profile Index Avg Interval to “150 meters”, and Profile Index Wheel Path to “both.” Exit menu and go back to Run Profile Menu.
7. Select “Run Profile (L>)” from Run Profile Menu (see Section 2.3.5). Then, press space bar on keyboard or operator pendant to start recording profile data and immediately proceed to Step 8.

Note: There is a time lapse between the time the operator presses the space bar key or pendant and the time when the vehicle is bounced. Since the Stop Record Distance is set to be 300 m (see Step 5) and the IRI for evaluating the bounce test is computed for the distance between 150 m and 300 m (see Step 6), the operator must ensure that the vehicle is being bounced as described in Step 8 before the recording distance of 150 m is reached.

8. Stand on rear bumper of vehicle and jump on bumper or use one hand on rear of bumper and one hand on the gutter rail of the vehicle to induce a pitching motion on the vehicle. This motion should pitch the vehicle along the longitudinal direction with no sideways motion. This motion should corresponds to a 12 mm displacement of the bumper for each bounce (i.e., distance from highest position to lowest position is 12 mm during bouncing). Because the IRI value is computed for the distance between 150 m and 300 m (see Step 6), the vehicle must be bounced for the complete time duration corresponding to these limits. If for any reason, the bouncing of the vehicle commences after the 150 m has been reached, the test is considered invalid and must be repeated.
9. Stop bouncing when the end of run auditory signal is heard. Again, operator must ensure that vehicle is bounced until end of run. It is recommended that the operator perform a trial run and obtain a time estimate of how long it takes for the end of run to be reached. This time estimate should be used to bounce vehicle in those cases the test is performed at a location where the end of run auditory signal cannot be heard (e.g. traffic noise).
10. Exit program, use DOS “edit” command to open “I file” containing IRI values, and note the IRI value indicated for the 150 to 300 m recording distance. If the IRI value (average of left and right wheel path) is less than or equal to 0.10 m/km between these limits, both sensors are considered to be functioning properly.
11. Go back to Main Menu (see Section 2.3.3) and select “Off Line Menu.” Select “Profile Graphical Compare Program” from the Off Line Menu, and from the displayed menu select “Graphic Compare Profiles.” Type the filename that was entered in Step 4 (use correct path).

12. Set Begin to “150”, Track to “all”, and Print Port to “enabled.” Then, press “Return” to plot the graph. The plot will show the data recorded by the left, right and center sensors between 150 and 300 m. Compare printout of data recorded by the three sensors to verify the center sensor is functioning properly.
13. If the IRI value from Step 10 exceeds 0.10 m/km or the printout from Step 12 indicates that there may be a problem with the center sensor, repeat the test two or three times to see if the specified conditions can be achieved. If these conditions are satisfied, the sensors are considered to be working properly.
14. If the specified conditions (Steps 10 and 12) cannot be achieved, move the vehicle and perform the test at a different location. If the specified conditions still cannot be achieved, contact K.J. Law Engineers, Inc. for advice. It has been observed that flakes can form inside the infrared sensors due to corrosion and they can have a significant effect on the bounce test results. The inability of the sensors to achieve the specified tolerance could be related to this condition.

If an error in the equipment is found and fixed, the operator should re-evaluate the profile data that was collected during the previous day. If the problem was in a sensor that is located either in left or the right wheel path, the IRI values obtained during the previous day should be compared with those obtained from the last visit to that site. If data problems are suspected, such sections should be re-profiled.

A default header containing the information necessary to conduct the bounce test can be created, saved and recalled at a later time whenever the bounce test is performed.

When profile data are viewed through the K.J. Law off-line program, the left and right wheel path profiles are displayed on the monitor, with the left profile at the top and the right profile at the bottom. Pressing the “+/=“ key on the keyboard toggles the top display between the left and center sensor.

After operator completes calibration of displacement sensors and accelerometers (see Section 2.5), a bounce test should be performed and a printout of the profile recorded by the left, right and center sensors should be obtained. As all equipment should be functioning properly after a calibration, the magnitude of displacements in the printout can be used as a standard against which to compare the magnitude of displacements observed in the field. If different, it should alert the operator that there is a potential problem with the sensors. The operator should save the output obtained from the bounce test after it is calibrated, and use the "Profile Graphical Compare Program" to compare this profile to profiles obtained when the bounce test is performed in the field.

2.3.5 Entering Header Information

Before collecting profile data at a section, operator must go through a series of header menus in the software and input data relevant to that section as well as change several default settings in these menus. The main menu that is displayed on the computer terminal is shown below.

MAIN MENU

A> RUN PROFILE
B> CALIBRATION
C> DIAGNOSTICS
D> DISK UTILITIES
E> DISPLAY DATA
F> CONVERT PROFILE
G> OFF LINE MENU

X> EXIT TO DOS

Enter LETTER or Position And Press Enter - Press X to EXIT

To begin process of entering header information, select A (Run Profile). The following menu will then be displayed:

RUN PROFILE MENU

A>	SYSTEM SETUP
B>	RUN IDENTIFICATION
C>	RUN LOCATION
D>	RUN CONDITIONS
E>	RUN CONTROL
F>	OPTION SETUP
G>	STORE HEADER INFORMATION
H>	RECALL HEADER INFORMATION
I>	PRINT HEADER INFORMATION
J>	CREATE NEW HEADER
K>	HELP
L>	RUN PROFILE (DEFAULT.P1)
M>	TRANSFER FROM RAM TO DISK
N>	DISPLAY LAST RUN
O>	DISK UTILITIES
X>	EXIT

Enter LETTER Or Position And Press Enter - Press X to EXIT

To create a new header file, operator should select "J (Create New Header)". The program will then go through the following menus to create the header file.

1. System Setup
2. Run Identification
3. Run Location
4. Run Conditions
5. Run Control
6. Options Setup

The first menu displayed will be the System setup menu which is described next.

2.3.5.1 System Setup

The following parameter settings should be used for the System Setup.

A>	FILTER WAVELENGTH	:	100 (meters)
B>	GRAPH LENGTH	:	400 (mtr)
C>	GRAPHICS SCALE	:	50 (mm)
D>	FILTER INITIALIZE ON RECORD	:	DISABLE

E>	INDEX PAUSE ON RECORD	:	DISABLE
F>	PRINT HEADER ON EXIT	:	DISABLE
G>	PRINT INDEX FILE ON EXIT	:	DISABLE
H>	PROFILE STORAGE	:	ENABLE
I>	DRIVERS DISPLAY UNITS	:	METRIC
J>	FORM FEED PRINTER	:	
K>	TEST MODE OSCILLATOR	:	DISABLE
L>	COMMENTS	:	
X>	EXIT MENU		

Enter LETTER Or Position and Press Enter - Press X to EXIT

The Graphics Scale refers to the y-axis scale that is displayed on the screen when collecting profile data. A value of 50 mm should be sufficient for most roads. Rough roads may require a greater value. Selecting “Graphics Scale” and pressing the “Enter” key will toggle through the available values for Graphics Scale. For rough roads operator may select a suitable value based on experience. The value that is selected for Graphics Scale affects how data is displayed on screen, but does not have any effect on data that is collected and recorded.

The operator should press “X” to proceed to the next menu, which is the Run Identification Menu.

2.3.5.2 Run Identification

An example of a completed Run Identification menu is presented below.

A>	RUN NUMBER	:	1
B>	OUTPUT FILE NAME	:	364018MC
C>	OUTPUT FILE DIRECTORY	:	PROFILES
D>	AUTO FILE NAME INCREMENTING	:	ENABLE
E>	OPERATOR/DRIVER	:	CK/RS
F>	VEHICLE IDENTIFICATION	:	68663
G>	FLOPPY DISK NUMBER	:	

H> COMMENTS :

X> EXIT MENU

Enter LETTER Or Position And Press Enter - Press X to EXIT

The following fields in the Run Identification menu should be filled by the operator: Run Number, Output File Name, Output File Directory, Auto File Name Incrementing, Operator/Driver, and Vehicle Identification. The entries that should be entered for each of these items are described next.

Run Number: Set to 1.

Output File Name: Specify based on file naming convention described in section 2.2.4.3.

Output File Directory: Directory where data files will be saved; enter an appropriate directory. If file directory does not exist, it will be created.

Auto File Name Incrementing: Set to ENABLED.

Operator/Driver: Enter names of operator and driver. Each person should be identified by a two digit character; first letter of their first and last name. Operator and driver names should be separated by a backslash (e.g., CK/RS). If profiler is used as a one person operation, operator and driver name would be the same (e.g., CK/CK).

Vehicle Identification: Enter last five digits of the vehicle identification number (VIN).

Once operator has completed entering the required data, press the “X” key to advance to the next menu, which is Run Location.

2.3.5.3 Run Location

The Run Location menu is presented below.

A>	ROAD DESCRIPTION	:	
B>	LANE MEASURED	:	
C>	DIRECTION	:	NORTH
D>	HORIZONTAL OFFSET	:	
E>	BEGINNING DESCRIPTION	:	
F>	BEGINNING STATION	:	
G>	BEGINNING KILOMETER POST	:	
H>	ENDING DESCRIPTION	:	
I>	ENDING STATION	:	
J>	ENDING KILOMETER POST	:	
K>	COMMENTS	:	
L>	EDIT EVENT DESCRIPTIONS	:	
X>	EXIT MENU		

Enter LETTER Or Position And Press Enter - Press X to EXIT

The following entries should be made in this menu.

Road Description: Enter route number where section is located (e.g. I-88).

Lane Measured: Enter Inside (Inside Lane) or Outside (Outside Lane). The outside lane is the lane adjacent to the shoulder at the right edge of the road.

Direction: Select appropriate lane direction (North, East, South or West); use “Enter” key to toggle between directions.

Once these data items have been entered, press “X” to advance to the next menu, which is Run Condition.

2.3.5.4 Run Conditions

The Run Condition menu is presented below.

A	ROAD SURFACE MATERIAL	:
B	ROAD CONDITION	:
C	TEMPERATURE	:
D	CLOUD CONDITIONS	:
E	COMMENTS	:
X	EXIT MENU	

Enter LETTER Or Position And Press Enter - Press X to EXIT

The menu items that need to be entered are: Road Surface Material, Road Condition, Temperature, Cloud Conditions, and Comments.

Road Surface Material: Valid entries for road surface type are A-CC for asphalt surfaced pavements and P-CC for Portland Cement Concrete surfaced pavements. The notations A-CC and P-CC must be used, otherwise an error message will be generated when the PROFSCAN program is run.

Road Condition: Describe surface condition of pavement; use V. Good (Very Good), Good, Fair or Poor. The following guidelines should be used to determine the road conditions. The severity levels that are described correspond to the definitions given in the LTPP Distress Identification Manual [(7)].

1. V. Good: Pavement does not show any distress.
2. Good: Pavement exhibits few visible signs of surface deterioration. Asphalt surfaced pavements may show low severity cracks, and Portland Cement Concrete (PCC) pavements may show low severity cracks and spalling.
3. Fair: Typical distresses on asphalt concrete surfaced sections can include the following distresses in a low to medium severity - rutting, block or edge cracking, transverse and longitudinal cracking, and patching. Typical distresses on PCC pavements can include the following distresses in a low to medium severity - spalling, transverse and longitudinal cracking, faulting, and patching.

4. Poor: Pavements in this category have deteriorated to such an extent that they affect the speed of free-flow traffic. Typical distress on asphalt surfaced sections include the following distresses in a medium to high severity - rutting, transverse and longitudinal cracking, potholes. Typical distress on PCC pavements can include the following distresses in a medium to high severity - spalling, transverse and longitudinal cracking, faulting and patching.

Temperature: Air temperature (in degrees Centigrade) at time of test.

Cloud Conditions: Describe cloud conditions as follows: Clear, P. Cloudy (Partly Cloudy), or Cloudy. Use the following guidelines: Clear - sunny sky, Cloudy - sun cannot be observed, P. Cloudy - sun is sometimes covered by clouds.

Once these fields have been completed, press "X" key to advance to the next menu, which is Run Control.

2.3.5.5 Run Control

The following parameter settings should be used in the Run Control Menu.

A>	DMI	:	ENABLE
B>	DMI UNITS	:	METERS
C>	DMI START VALUE	:	0.00 (meters)
D>	DMI DIRECTION	:	ASCENDING
E>	DMI START METHOD	:	PROFILE RECORD
F>	START RECORD METHOD	:	PHOTOCELL
G>	START RECORD DMI DISTANCE	:	
H>	STOP RECORD METHOD	:	DISTANCE
I>	STOP RECORD DISTANCE	:	152.50 (Meters)
J>	ACTIVE PHOTOCELL	:	VERTICAL
K>	COMMENTS	:	
X>	EXIT MENU		

Enter LETTER Or Position And Press Enter - Press X to EXIT

The above parameter settings are required in the Run Control Menu.

Note that the Start Record Method is “Photocell”. Pointer should be placed over this menu item and the “Enter” key should be pressed to toggle through available entries in this field until “Photocell” is selected.

The Stop Record Method should be Distance. Pointer should be placed over this menu item and the “Enter” key should be pressed to toggle through available entries in this field until distance is selected.

The Stop Record Distance for GPS, SMP and WIM sections should be 152.50 meters. The distance to be entered for SPS sections are presented in section 2.4.2. If a GPS section is profiled with a WIM section, distance should be set such that both sections are covered.

The active photocell should be “Vertical Photocell”.

Once the above data items have been completed, operator should press “X” key to advance to the next menu, which is Option Setup.

2.3.5.6 Options Setup

The following parameter settings should be used in the Options setup.

A>	PROFILE INDEX TYPE	:	IRI
B>	PROFILE INDEX WHEEL PATH	:	BOTH
C>	PROFILE INDEX AVG INTERVAL	;	30 (METERS)
D>	PROFILE INDEX SIM SPEED	:	80 (KM/H)
E>	INDEX FILE KEYBOARD EVENTS	:	DISABLE
F>	AVG INTERVAL TYPE	;	FIXED
G>	COMMENTS	:	NONE

X> EXIT MENU

Enter LETTER Or Position And Press Enter - Press X to EXIT

Within each of the menu fields, the “Enter” key can be used to toggle between values in order to select the appropriate parameter setting. Operator should press the “X” key to go back to the Run Profile Menu.

2.3.5.7 Save Header Information

Information that was entered in the header file should be saved to a Header File. Select “Store Header Information (G)” option from the following menu, and enter an eight digit file name to save the header information. Next select option “M” to save the header file from RAM to hard disk.

A> SYSTEM SETUP
B> RUN IDENTIFICATION
C> RUN LOCATION
D> RUN CONDITIONS
E> RUN CONTROL
F> OPTION SETUP
G> STORE HEADER INFORMATION
H> RECALL HEADER INFORMATION
I> PRINT HEADER INFORMATION
J> CREATE NEW HEADER
K> HELP
L> RUN PROFILE (DEFAULT.P1)
M> TRANSFER FROM RAM TO DISK
N> DISPLAY LAST RUN
O> DISK UTILITIES
X> EXIT

Enter LETTER or Position And Press Enter - Press X to EXIT

2.3.5.8 Recall Header Information

Instead of going through the steps outlined above to generate a header file, an existing header file can be recalled and modified. If this procedure is used, "Recall Header Information" should be selected from the Run Profile Menu, and an existing header file name should be typed. Operator should then go through menus described in Sections 2.3.5.1 through 2.3.5.6, make appropriate changes to header file relevant to section that is being profiled.

2.3.6 Data Collection

The following steps should be followed for data collection.

1. About 600 m prior to the test section, select "Run Profile (A>)" from the main menu. The following menu will be displayed:

A>	SYSTEM SETUP
B>	RUN IDENTIFICATION
C>	RUN LOCATION
D>	RUN CONDITIONS
E>	RUN CONTROL
F>	OPTION SETUP
G>	STORE HEADER INFORMATION
H>	RECALL HEADER INFORMATION
I>	PRINT HEADER INFORMATION
J>	CREATE NEW HEADER
K>	HELP
L>	RUN PROFILE (DEFAULT.P1)
M>	TRANSFER FROM RAM TO DISK
N>	DISPLAY LAST RUN
O>	DISK UTILITIES
X>	EXIT

2. Invoke profile data collection program by selecting "Run Profile (L>)". A graphical display of the left and right profiles is generated on the screen. This screen indicates that Recording is "On" and Photo Alert is "Off". The file name specified for data

storage in the Run Identification Menu (section 2.3.5.2) as well as the vehicle speed are also displayed on the screen.

3. Driver should attain a constant test speed of 80 km/h at least 100 m before beginning of test section and align the vehicle along the wheel paths. As described in section 2.2.4.4, a speed lower than 80 km/h may be used depending on posted speed limit, heavy traffic or safety considerations.
4. Press Operator Pendent or keyboard space bar to arm photocell after passing the lead in stripe located before test section. The message “Photocell Alert On” and “Recording On” will appear at the top of the graph on the screen.
5. Once event mark is detected by photocell, the monitor display is erased and the recorded profile starts at beginning of grid. If photocell is not triggered when event mark is passed, clean the photocell and repeat the run and see if the photocell triggers. If the photocell still fails to trigger, the operator should adjust the threshold control for photocell and see if photocell will trigger. If this is not successful, operator should use the lateral photocell. When the lateral photocell is used, operator will have to change “Active Photocell” in “Run Control Method” to “Horizontal” prior to collecting data (See section 2.3.5.5). Refer to section 2.2.4.5 for information regarding the use of the lateral photocell.
6. After the test section has been profiled, note any factors that could have affected the profile data collection for that run in the Profilometer® Field Activity Report Form (e.g., traffic, heavy winds).
7. Once the computer gets out of the profile display mode, type any comments pertaining to the run that could have affected profile data collection. (e.g., high traffic volumes, heavy winds, damp pavement, test speed was less than 80 km/h) and then press “Enter”.
8. Once the driver stops the vehicle at a suitable location, the data can be saved on the hard disk. This should be done after each run since the profile data stored in the virtual memory can be lost if the power to the computer fails. Where the turn around distances are relatively short, the operator may wait to transfer the data to the hard disk until all runs have been completed. The data can be transferred from the RAM

drive to the hard disk by selecting the option "M (Transfer data from RAM to disk)" from the Profile Run Menu (see menu at the beginning of section 2.3.5). The data will be put in the directory specified in the Run Identification Menu (see section 2.3.5.2) and copied to the specified filename.

9. Follow the procedures outlined in section 2.2.5 to obtain a set of acceptable runs at the site.
10. Once testing at a site is completed make backup copies as outlined in section 2.2.4.8.
11. The operator should verify that the form "LTPP Profilometer Field Activity Report Form" (see section 2.7.1) and "Status of the Regions Test Section" (see section 2.7.2) are filled before leaving the test site.

2.3.7 Data Backup

The profile data should be backed up following the procedures described in section 2.2.4.8.

2.4 TESTING SPS SECTIONS

2.4.1 General Background

This section describes field testing procedures to be followed when testing SPS sites which are different than the procedures used for GPS sections. However, note that except for the exceptions described in this section all other information presented in the earlier sections of this manual are valid when SPS sites are being tested.

A SPS site consists of a number of test sections with a transition area between the adjacent sections. During a Profilometer® run at a SPS site, profile data are collected for the entire site, which includes test sections as well as transition areas.

2.4.2 Length of Test Sections

Unlike GPS test sections which are always 152.4 m in length, the length of test sections at an SPS project can vary. The operator may elect to break the SPS project into two sections for profiling depending on location of test sections as well as turn around locations. For example, if there is a large transition distance between two groups of test sections, and the turn around is located in the transition area, the operator may elect to profile the SPS project as two sections.

The maximum section length that the PROQUAL software can process is limited to 9.99 km. Therefore, the maximum distance that can be profiled in one profiler run should not exceed 9.99 km. If the length of a SPS project exceeds 9.99 km, that project should be profiled as two separate sections, with the length of each section being less than 9.99 km.

2.4.3 Operating Speed

Guidelines regarding operating speed described in section 2.2.4.4 should be followed when testing SPS test sections. When SPS test sections are tested, the transition area between the sections may be used to adjust vehicle speed to 80 km/h before next section is tested. If there is traffic in front of the Profilometer®, its speed can be initially decreased in the transition section to give more headway between the vehicle in front. Thereafter, the Profilometer® must be brought up to a constant speed of 80 km/h before entering next test section.

2.4.4. Event Marks

Event marks are used to identify starting point of each test section within a SPS site. The PROFSCAN program uses these event marks to compute the IRI of each test section. If vertical photocell is not triggered during a profile run, lateral photocell should be used to initiate data collection. Refer to section 2.2.4.5 for information related to the use of the lateral photocell.

2.4.5 Number of Runs

Five profiler runs in each test section within a SPS project must satisfy the acceptance criteria described in section 2.2.5.2. The PROFSCAN program is capable of computing the IRI value of individual test sections within a SPS project by identifying test sections using event marks. The procedure for doing this within PROFSCAN is described in section 3 of the PROQUAL manual. [6] Operator should study IRI computed for each run to ensure that repeatable data are obtained between runs. The procedure outlined in section 2.2.5 should be followed in order to obtain an acceptable set of runs at a SPS project.

2.4.6 Header Generation

The procedures outlined in section 2.3.5 for header generation for GPS test sections should also be followed for SPS test sections. However, differences do exist for SPS sections in the following menus.

<u>1. System Setup (see section 2.3.5.1):</u>
The System Setup Menu should indicate the parameters settings specified in section 2.3.5.1, except Graph Length and Graphics Scale. Graph Length refers to section length that can be displayed on screen of monitor; default value is 400 meters, but this value can be toggled to 800 or 1600 meters by pressing the “Enter” key. Depending on length of the SPS project, an appropriate graph length should be selected. This option only affects data that is displayed on screen and does not affect profile data collection or recording. For long SPS projects entire length cannot be displayed in a single screen. For such sections, after selected graph length is displayed, screen is reset and next part of profile is displayed.

Graphics Scale refers to y-axis scale that is displayed on screen when collecting profile data. A value of 50 mm should be sufficient for most roads. Rough roads may require a greater value. To change graphics scale, position pointer over that menu option and press the “Enter” key to toggle through available values. This option only affects data that is displayed on the screen and does not affect profile data collection or data recording.

2. Run Identification (see section 2.3.5.2):

The procedures described in section 2.2.4.3 should be used to specify the output file name. An appropriate Output File Directory should also be entered.

3. Run Control Method (see section 2.3.5.5):

The Run Control Menu should indicate the parameter settings specified in section 2.3.5.5, except for Stop Record Distance. As for GPS sections, Stop Record Method for SPS projects should be Distance. Operator should refer to site layout plans and obtain length of SPS test sections to be tested. To guard against discrepancies between layout plans and as-built sections the operator may add a distance such as 25 m to the distance obtained from site layout plan. After selecting “distance” as stop method in the Run Control Menu, enter length to be profiled.

If operator is not certain about the length to be profiled, following procedure can be used to obtain length of site. Operator should set Start Record Method to “photocell”, and Stop Record Method to “pendant”, profile entire site and press Operator Pendant after end of the last test section. The total profiled length is displayed on the screen. Data that was collected should be discarded as the purpose of this run was to obtain the project length. Operator should set the parameter settings in the Run Control Menu to those shown in section 2.3.5.5, but change Stop Record Distance to project length obtained using above described procedure.

If discrepancies between profiled length of the project and the test section layout diagram are noted, the operator should use a measuring wheel to record the correct layout of test sections. The RCO should be informed of the discrepancy.

2.4.7. Hardcopy of Profile

After collecting profile data, use "Display Data" option from the K.J. Law off-line menu or use PROQUAL to obtain a printout of profile data for one profiler run of the entire SPS project. Regenerate profile data at 400 m intervals or appropriate interval if project is longer and obtain a hardcopy of each screen. Compare the output of the left and right profiles with the center profile to see if center sensor is functioning correctly.

2.4.8 Data Backup

The data collected at SPS projects should be backed up using the procedures described in section 2.2.4.8.

2.5 CALIBRATION

2.5.1 General Background

The infrared displacement sensors, accelerometers and the distance measurement system should be calibrated monthly. However, the calibration of these equipment should be done whenever problems are suspected.

The distance measuring system, infrared displacement sensors and the accelerometers should be calibrated when tires are replaced, suspension repairs are performed or when wheels are aligned. The infrared displacement sensors and accelerometers must be calibrated whenever a sensor is moved or replaced.

The distance measuring system, infrared displacement sensors and the accelerometers should be calibrated when repairs are performed on these components or to the data acquisition system.

The power to the electronic equipment should be turned on for about 20 minutes prior to performing any calibration so that the electronic equipment would warm up and stabilize.

2.5.2 Calibration of Infrared Sensors

The calibration procedure involves establishing an initial height reference and then precisely measuring the distance from the infrared sensors to calibration blocks whose thickness are known.

Calibration of infrared sensors should be performed indoors and on a level surface with the engine turned off. A hand level placed on the sensor bar can be used to check if the surface is level. The vehicle should be elevated 37.5 mm prior to performing the calibration. Each wheel of the vehicle should be placed on a piece of construction lumber that is 37.5 mm in height to achieve this elevation. The four pieces of construction lumber that are placed under the wheels should have the same height. External power should be used during calibration. Operator should be outside vehicle when calibration is performed. Operator should adjust computer monitor so that it can be seen from outside the vehicle, and keyboard should be placed on floor of van. Do not enter vehicle, bounce or bump vehicle, or lean on vehicle during calibration. To begin calibration process, select "Calibration" from main menu. The following calibration menu will then be displayed:

A> CALIBRATE IR SENSORS
B> DISPLAY IR SENSORS

C> CALIBRATE ACCELEROMETER
D> DISPLAY ACCELEROMETERS

E> CALIBRATE WHEEL PULSE ENCODER

F> ENTER CALIBRATION VALUES
G> STORE CALIBRATION VALUES
H> PRINT CALIBRATION VALUES

I> DISK UTILITIES

J> HELP
X> EXIT

Enter Letter Or Position and Press Enter - Press X to EXIT

The following procedure should be followed to calibrate sensors.

1. Select "Calibrate IR Sensors" from menu to begin calibration. The following screen will be displayed:

   =

   IF YOU WANT TO BEGIN THE 1ST STEP FOR CHECKING

   THE CALIBRATION OF AN IR SENSOR PRESS ENTER NOW

   =

   A> Begin Calibration Check C Exit

2. Press the "Enter" key and the following menu will be displayed.

   STEP 1 STEP 2 STEP 3 STEP 4

   CAL TYPE 1

   STEP 1: SELECT THE TYPE OF CALIBRATION TEST DESIRED

# BLOCKS	THICKNESS
A> 1) 3 BLOCKS	25 MILLIMETERS
X> 2) 5 BLOCKS	25 MILLIMETERS

3. The three blocks calibration should be used for calibrating sensors. Select "A" to perform the three blocks calibration. The following menu will then be displayed; Select "Y" to proceed.

   STEP 1 STEP 2 STEP 3 STEP 4

CAL TYPE 1

STEP 1: SELECT THE TYPE OF CALIBRATION TEST DESIRED

	# BLOCKS	THICKNESS
A>	1) 3 BLOCKS	25 MILLIMETERS
X>	2) 5 BLOCKS	25 MILLIMETERS

DO YOU WANT TO GO ON TO CALIBRATION STEP 2: (Y/N) ?

4. The following menu will then be displayed. Press space bar to select infrared sensor to be calibrated. Pressing space bar will toggle users through the left, right and center sensor. Once desired sensor is selected, press the “Enter” key to proceed.

STEP 1 STEP 2 STEP 3 STEP 4
CAL TYPE 1

STEP 2: ENTER THE SENSOR THAT YOU WANT TO CALIBRATE
PRESS SPACE BAR TO ADVANCE TO SENSOR DESIRED
THEN PRESS ENTER
SENSOR = LEFT

The following prompt will then be displayed; select “Y” to proceed.

DO YOU WANT TO GO ON TO CALIBRATION STEP 3 Y/N

5. The following screen will then appear.

STEP 1 STEP 2 STEP 3 STEP 4
CAL TYPE 1 LEFT

STEP 3: ALIGN THE CALIBRATION PLATFORM UNDER THE SENSOR
PRESS LETTER “H” TO TAKE THE BASE HEIGHT READING

At this stage, place leveling platform below sensor that is being calibrated (left sensor for this example). The leveling plate should be placed such that infrared light is at center of plate. Infrared light should be viewed using the infrared sensitive card, which will show five dots of light. Leveling platform should be positioned such that dots are near center of leveling platform. On a sunny day it is difficult to observe the location of the dots using the infrared sensitive card. Therefore, it is recommended that the operator note the exact position of the dots when the base plate is at a specified position in relation to the sensor bar by viewing the dots under ideal conditions. The leveling platform has a built-in circular level and three adjusting knobs; level platform using these knobs. Place steel calibration plate on top of leveling platform such that its position or level is not disturbed. On completion, press the “H” key to record base height.

6. The base height from step 5 will appear on the screen as shown below (value of 280 is assumed for this example); press “Y” to proceed.

STEP 1	STEP 2	STEP 3	STEP 4
CAL TYPE 1 LEFT		BASE = 280.00	

STEP 3: ALIGN THE CALIBRATION PLATFORM UNDER THE SENSOR
PRESS LETTER ‘H’ TO TAKE THE BASE HEIGHT READING
THE BASE HEIGHT READING HAS BEEN RECORDED.

ENTER THE ACTUAL MEASURED BASE HEIGHT = 280.00
DO YOU WANT TO GO ON TO CALIBRATION STEP 4: (Y/N) ?

7. Next, the following screen will be displayed.

STEP 1 STEP 2 STEP 3 STEP 4
CAL TYPE 1 LEFT BASE = 280.00 BLOCK 1

STEP 4: PUT CALIBRATION BLOCK #1 UNDER THE SENSOR
PRESS THE “F1” KEY TO TAKE HEIGHT READING # 1

Place calibration block in center of leveling platform with 25 mm side in vertical position. Use infrared sensitive card to view location of infrared dots when placing block. Place calibration plate on top of calibration block such that it is centered on top of block. Press “F1” key to record height reading. The following menu will then be displayed (value of H1 is assumed for this example); select “Y” to proceed.

STEP 1 STEP 2 STEP 3 STEP 4
CAL TYPE 1 LEFT BASE = 280.00 BLOCK 1

H1 = 24.683

STEP 4: PUT CALIBRATION BLOCK #1 UNDER THE SENSOR
PRESS THE “F1” KEY TO TAKE HEIGHT READING # 1
HEIGHT READING # 1 HAS BEEN RECORDED
DO YOU WANT TO GO ON TO THE NEXT STEP: (Y/N) ?

8. After **“**Y” is selected, the following screen is displayed:

STEP 1 STEP 2 STEP 3 STEP 4
CAL TYPE 1 LEFT BASE = 280.00 BLOCK 2

H1 = 24.683

STEP 4: PUT CALIBRATION BLOCK #2 UNDER THE SENSOR
PRESS THE "F2" KEY TO TAKE HEIGHT READING # 2

Place calibration block on leveling platform such that 50 mm side of calibration block is vertical. Observe position of infrared dots when placing block to make sure that they are at center of vertically placed block. Place calibration plate on top of block such that it is centered on top of block, and then press the "F2" key. This will lead to the following screen (value of H2 is assumed for this example); press "Y" to proceed.

```
STEP 1        STEP 2        STEP 3        STEP 4
CAL TYPE 1  LEFT          BASE = 280.00  BLOCK 2

H1 = 24.683          H2 = 49.692

STEP 4: PUT CALIBRATION BLOCK #2 UNDER THE SENSOR
        PRESS THE 'F2' KEY TO TAKE HEIGHT READING # 2
        HEIGHT READING # 2 HAS BEEN RECORDED
        DO YOU WANT TO GO ON TO THE NEXT STEP: (Y/N)?
```

9. The following menu will then be displayed.

```
STEP 1        STEP 2        STEP 3        STEP 4
CAL TYPE 1  LEFT          BASE = 280.00  BLOCK 3

H1 = 24.683          H2 = 49.692

STEP 4:   PUT CALIBRATION BLOCK #3 UNDER THE SENSOR
          PRESS THE 'F3' KEY TO TAKE HEIGHT READING # 3
```

Place calibration block on leveling platform such that 75 mm side of calibration block is vertical. Observe position of infrared dots when placing block to make sure that they are at center of vertically placed block. Place calibration plate on top of block such that it is centered on top of block, and then press the "F3" key. The following screen will then be displayed (for this example H3 is assumed to be 74.534); press "Y" to proceed.

```
STEP 1          STEP 2          STEP 3          STEP 4
CAL TYPE 1  LEFT            BASE = 280.00  BLOCK 3

H1 = 24.683             H2 = 49.692    H3 = 74.534


STEP 4:          PUT CALIBRATION BLOCK #3 UNDER THE SENSOR
                 PRESS THE 'F3' KEY TO TAKE HEIGHT READING # 3
                 HEIGHT READING # 3 HAS BEEN RECORDED
                 DO YOU WANT TO GO ON TO THE NEXT STEP: (Y/N)?
```

10. Press "N" in the next screen (see below) to proceed.

```
STEP 1     STEP 2     STEP 3          STEP 4
CAL TYPE 1  LEFT            BASE = 280.00  BLOCK 3

H1 = 24.683             H2 = 49.692    H3 = 74.534

STEP 5:    YOU HAVE NOW COMPLETED THE CALIBRATION CHECK
```

DO YOU WANT TO REPEAT ANY STEPS (Y/N) ?

11. The following screen is displayed (numbers are for this example); press “Y” to proceed.

SAMPLES	ACTUAL	ERROR
1 = 24.683	25.00	- 0.317
2 = 48.692	50.00	- 0.308
3 = 74.534	75.00	- 0.468

DO YOU WISH TO CALIBRATE (Y/N) ?

After pressing “Y” the following screen is displayed (Range, Variance, Gain 2, Offset and Total p-p values shown are only examples). Record the measured heights of blocks that are indicated on screen (24.683, 48.692, and 74.534 for this example) in the Sensor Calibration Log (see Appendix I).

SAMPLES	ACTUAL	ERROR
1 = 24.683	25.00	- 0.317
2 = 48.692	50.00	- 0.308
3 = 74.534	75.00	- 0.468

Range = - 1.8580

Variance = 0.017274

Gain 2 = -1.8600

Offset = 3424.0

Total p-p = 0.0691

If Total p-p reading is greater than 0.007, repeat calibration process. If Total p-p value is less than 0.007, sensors have been correctly calibrated.

12. Repeat calibration test for other two sensors; follow steps 1 through 11 for each of them.

13. Go back to calibration menu, and the following screen will be displayed:

A> CALIBRATE IR SENSORS
B> DISPLAY IR SENSORS

C> CALIBRATE ACCELEROMETER
D> DISPLAY ACCELEROMETERS

E> CALIBRATE WHEEL PULSE ENCODER

F> ENTER CALIBRATION VALUES
G> STORE CALIBRATION VALUES
H> PRINT CALIBRATION VALUES

I> DISK UTILITIES
J> HELP
X> EXIT

Enter Letter Or Position and Press Enter - Press X to EXIT

Select “Display IR Sensors” from above menu. Sensor readings will be showed both numerically and graphically. The information displayed can be used to verify that sensors are operating properly. Any excessive noise in the measuring system will be indicated by large variations in one or more of sensor readings.

14. Select “Store Calibration Values” from calibration menu to store calibration factors. For Calibration comment, enter location where calibration was performed. Obtain a printout of calibration factors.

2.5.3 Calibration of Accelerometers

Accelerometers have a built in calibration system which allows them to be calibrated electronically. Their calibration should be performed indoors with vehicle on a level surface and engine turned off. A hand level placed on the sensor bar can be used to check if the sensor bar is level. The location should be free of any vibrations. External power should be used during calibration. Operator should be outside of vehicle when calibration is performed. Operator should adjust computer monitor so that it can be seen from outside vehicle, and keyboard should be placed on floor of van. Do not enter vehicle, bounce or bump vehicle, or lean on vehicle during calibration. To begin calibration process select "Calibration" from main menu. The following calibration menu will then be displayed:

A> CALIBRATE IR SENSORS
B> DISPLAY IR SENSORS

C> CALIBRATE ACCELEROMETER
D> DISPLAY ACCELEROMETERS

E> CALIBRATE WHEEL PULSE ENCODER

F> ENTER CALIBRATION VALUES
G> STORE CALIBRATION VALUES
H> PRINT CALIBRATION VALUES

I> DISK UTILITIES
J> HELP
X> EXIT

Select "Calibrate Accelerometer" to perform calibration of accelerometers. Computer will automatically perform calibration and display results. In the "Calibration Menu", select "Store Calibration Values" to save calibration values. Obtain a printout of calibration values.

2.5.4 Calibration of Wheel Pulse Encoder

The wheel encoder is calibrated by driving vehicle over a known distance to calculate distance scale factor; i.e. distance traveled per 100 pulses. This procedure requires pre-setting a driving course. Operator enters actual distance traveled and computer calculates scale factor.

An accurately measured section of 300 m should be used to calibrate wheel encoder. This section should be located on a straight portion of roadway that is reasonably level and having low traffic volume. Speed limit at site should be at least 80 km/h. This section should be in an area where vehicle can be driven at a constant speed without interruptions. Section should be measured with a steel tape using standard surveying procedures. The steel tape should be corrected for temperature, and the proper tension should be applied during the layout of the section.

The operator should drive the vehicle for about 6 to 8 km (4 to 5 miles) at highway speeds prior to calibration. The operator should adjust the tire pressure of the front tires such that the inflation pressure is between 413 and 448 kPa (60 and 65 psi) before the vehicle is driven over the calibration section.

To perform calibration of wheel encoder, select “Calibration” from the main menu. The following menu is then displayed:

```
A>      CALIBRATE IR SENSORS
B>      DISPLAY IR SENSORS

C>      CALIBRATE ACCELEROMETER
D>      DISPLAY ACCELEROMETERS

E>      CALIBRATE WHEEL PULSE ENCODER

F>      ENTER CALIBRATION VALUES
G>      STORE CALIBRATION VALUES
H>      PRINT CALIBRATION VALUES
```

I> DISK UTILITIES
J> HELP
X> EXIT

Select "Calibrate Wheel Pulse Encoder" to begin calibration. Cones with reflective marks should be placed at start and end of section.

The following parameter settings should be used in this menu:

1. Calibration Start Method: Set to Photocell
2. Calibration Stop Method: Set to Photocell
3. Option C should be Test Wheel Pulse Calibration System
4. Photocell Select: Set to Horizontal.

If a section that has been previously laid out with white stripes placed at the beginning and end of test section is used for calibration, vertical photocell can be used. If vertical photocell is used, Photocell Select should be set to "Vertical".

An example completed screen where the horizontal photocell is specified should have the following format (value of distance scale factor shown is an example).

A> CALIBRATION START METHOD: PHOTOCELL
B> CALIBRATION STOP METHOD: PHOTOCELL
C> TEST WHEEL PULSE CALIBRATION SYSTEM
D> AUTOMATIC DISTANCE SCALE FACTOR CALCULATION
E> ENTER DISTANCE SCALE FACTOR: 1.3057621 meters/100 pulses
F> PHOTOCELL SELECT: HORIZONTAL
X> EXIT MENU

The wheel encoder calibration should be performed at a speed of 80 km/h. The following procedure should be followed when performing this test.

1. Press operator pendant switch once (or press space bar once) to arm photocell prior to reaching beginning of test section.
2. Press operator pendant switch once (or press space bar once) to arm photocell after passing start of section and prior to reaching end of test section
3. Terminal will display the following message (distance scale factor shown is an example):

   DISTANCE SCALE FACTOR 1.5668959 meters/100 pulses

   DISTANCE TRAVELED (meters) = 0.00

   ENTER THE DISTANCE THAT YOU HAVE TRAVELED IN METERS _____

   Enter distance of test section (in meters), and the software will compute and display the distance scale factor. Save calibration factor and obtain a printout of this.

2.6 EQUIPMENT MAINTENANCE AND REPAIR

2.6.1 General Background

Responsibility for equipment maintenance and repair rests with each RCO. Decisions required for proper maintenance and repair should be based on testing schedule and expedited as necessary to prevent disruption of testing. Maintenance activities on the Profilometer® should be performed prior to mobilization for testing. During a testing period there will be little time to do more than the required daily checks prior to testing. Specific, detailed maintenance procedures are contained in the manuals provided with each piece of equipment (see References). Operator must become familiar with the maintenance recommendations contained in all equipment manuals. Maintenance/Repair work to be performed can be classified as: routine maintenance, preventive maintenance and unscheduled maintenance.

2.6.2 Routine Maintenance

Routine maintenance includes work that can be performed by the operator. The Daily Check List (see Appendix I) includes a list of maintenance activities to be performed every day. These procedures include checking vehicle lights, checking under the vehicle for fluid leaks, checking fluid levels in vehicle and cleaning the glass covers of the sensors and the photocell. These items are the most basic and easily performed maintenance measures and should always be done prior to using equipment every day. If any problems are noted, they should be entered in the Profilometer Log (section 2.7.4) that should be maintained in the vehicle, and appropriate action should be taken to correct noted problems.

Displacement sensors are sealed in optical units and they will not function correctly if seal is broken. Cracked or chipped glass windows will cause moisture damage to occur and this can lead to failure of system. If any signs of physical damage occur to the sensor windows, they should be replaced. The water level in the batteries should be checked monthly.

2.6.3 Scheduled Major Preventive Maintenance

Scheduled major preventive maintenance services are services that are performed at scheduled intervals. Scheduled preventive maintenance activities on the vehicle should be performed following the manufacturer's heavy use guidelines. These include activities such as oil changes that are performed every 3,000 miles. Checking of drive belts, hoses, battery cable connections etc. should be performed when the oil is changed in the vehicle. The LTPP Major Maintenance/Repair Report Form (see Appendix I) will be used by operator to report necessary services performed and will also serve to inform RCO of the condition of Profilometer® on a regular basis.

2.6.4 Unscheduled Maintenance

These are unscheduled repairs. These repairs must be reported on the LTPP Major Maintenance/Repair Report form as an unscheduled maintenance activity.

Flakes can form inside the infrared sensors due to corrosion, and these may affect data collection. These flakes can be removed by removing the glass covering and then turning the sensor upside down, shaking them loose and wiping the lenses and the perimeter of the container. The glass covering of the sensor can be broken very easily during disassembly and extreme care should be taken when the glass covering is removed.

The LTPP Major maintenance / Repair Activity Report should be filled whenever a sensor is replaced or repaired. The procedures described in section 2.2.3.7 should be followed whenever a sensor is replaced or repaired.

2.7 RECORD KEEPING

There are seven types of records that should be forwarded to the RCO by the Profilometer® operator. They are:

1. LTPP Profilometer Field Activity Report
2. Status of the Regions Test Sections
3. Profscan Reports and Profile Plots
4. Profilometer Log
5. LTPP Major Maintenance/Repair Activity Report
6. Profilometer Calibration Reports
7. Infrared Sensor Calibration Log

A description of each of these forms/reports is presented in the following sections. If the items described for the Profilometer Log or the LTPP Major Maintenance/Repair Activity Report are being recorded by the operator following the standard operating procedures of the RCO, the filling of these forms may be omitted. It is acceptable for a region to use a form that has a different format than that presented for Status of Regions Test Sections and Infrared Sensor Calibration Log as long as the modified form contains all the items indicated in these two forms.

2.7.1 LTPP Profilometer Field Activity Report

The Field Activity Report (see Appendix I) records all activity to and from a site, as well as activities at the test site. This report should be filled out for all travel and testing days. For travel-only days the section for which traveling is being done should be noted. Entering IRI readings requested on this form is optional. If a region keeps this form in vehicle and uses IRI values as a check when section is profiled subsequently, IRI values should be entered. Operator may fill a copy of this form or use off-line program in the K.J. Law software to enter data and print this form. If off- line program is used, the "Print Field activity Report" option should be used to enter data and print form.

2.7.2 Status of the Regions Test Sections

The "Status of the Regions Test Section" form (see Appendix I) should be filled out at every test section. Recent maintenance or rehabilitation activities, condition of paint marks, missing LTPP signs and delineators as well as any other comments regarding the test section should be recorded on this form.

2.7.3 PROFSCAN Reports and Profile Plots

Two reports are generated for each test section by PROFSCAN. The Summary Report contains a statistical summary of IRI's for different runs at a test site. The Spike Report contains a record of spikes detected in the pavement profile. If no spikes are detected at a section, this report is not produced. Both reports must be attached to the associated Field Activity Report. A sample Summary Report and Spike Report are included in Appendix A of the PROQUAL Manual.(6)

The graph of the left, right and center sensor profiles that is printed through K.J Law software for each profile run should be attached to the PROFSCAN Report.

2.7.4 Profilometer Log

Operator should maintain a Profilometer Log in vehicle. Format of log is included in Appendix I. When operator performs daily checks on equipment, items needing attention should be noted on the Profilometer Log.

2.7.5 LTPP Major Maintenance/Repair Activity Report

This form is included in Appendix I. Vehicle and equipment operating costs are monitored with this form. All maintenance and repairs performed on vehicle or equipment should be reported on this form; including scheduled as well as unscheduled maintenance. This form should be submitted along with all receipts for maintenance activities.

2.7.6 Profilometer Calibration Reports

After a calibration is performed on displacement sensors, accelerometers, or wheel encoder, a printout of calibration factors should be obtained. The time, date and location where calibration was performed should be noted in the printout.

2.7.7 Infrared Sensor Calibration Log

This form is included in Appendix I. Each time when the infrared sensors are calibrated, the base height as well as height of the blocks that are obtained during calibration should be recorded on this form. For example, step 11 in section 2.5.2 shows the block heights that were recorded during calibration (24.683, 48.692, and 74.534 mm). These are the three heights that should be recorded in the sensor Calibration Log. The calibration log should be maintained in a three-ring binder.

2.8 TESTING WITH 690DNC PROFILOMETER

If the K.J Law 690DNC Profilometer® is used for data collection, the procedures outlined in document SHRP-P-378, "Manual for Profile Measurement: Operational Field Guidelines" should be followed [(8)]. This document describes the procedures to be followed when collecting data using the K.J. Law 690DNC Profilometer®. However, the latest FHWA directives regarding data collection that supersede information presented in this document should be followed. Procedures for processing data collected with the 690DNC Profilometer® using the PROQUAL software are described in section 8 of the PROQUAL Manual. [(6)]

3. PROFILE MEASUREMENTS USING THE FACE TECHNOLOGIES DIPSTICK

3.1 INTRODUCTION

The Face Technologies Dipstick® is a manually operated device for collection of precision profile measurements at rates greater than traditional rod and level survey procedures. However, the profile obtained from Dipstick® measurements may have a shift from the true profile because of systematic cumulative errors in the Dipstick® readings. The body of the Dipstick® houses an inclinometer (pendulum), LCD panels, and a battery for power supply. The Dipstick® sensor is mounted in such a way that its axis and line passing through footpad contact points are co-planar. The sensor becomes unbalanced as the Dipstick® is pivoted from one leg to the other as it is moved down the pavement, causing the display to become blank. After the sensor achieves equilibrium, the difference in elevation between the two points is displayed. The swivel footpads that have a diameter of 32 mm should be used for all measurements.

Each LTPP region has two Face Technologies Dipsticks®; a manual Dipstick® (Model 1500) and an automated Dipstick® (Model 2000). Both these Dipsticks® display data in millimeters. The spacing between the two feet of the Dipstick® is 305 mm for both models. When the automated Dipstick® is used for data collection, it should be used in manual mode, with data recorded manually.

Profile measurements on GPS and SPS sites that cannot be obtained using the LTPP Profilometer® should be completed using the Dipstick®. Decisions with respect to the need for Dipstick® measurements at these test sections should be made on a case-by-case basis by the responsible RCO personnel.

3.2 OPERATIONAL GUIDELINES

3.2.1 General Procedures

Dipstick® measurements are to be taken by personnel who have been trained in using the device and are familiar with the procedures described in this manual. Data collection using the Dipstick® is a two person operation, with one person operating the Dipstick®, and the other person recording the data. However, a single person can collect the data if that person uses a voice activated tape recorder to record the readings.

Detailed scheduling and traffic control at test sites must be coordinated by the RCO. All traffic control activities at test sites will be performed by personnel from either the state highway agency (in United States) or provincial highway agency (in Canada). Layout of site should not be undertaken until all applicable traffic control equipment is in-place.

3.2.2 LTPP Procedures

<u>Maintenance of Records:</u> Operator is responsible for forwarding all data collected during testing (see forms in Appendix II). In addition, operator is also required to forward other records related to Dipstick® operation, which are described in section 3.6, to RCO.

<u>Equipment Repairs:</u> RCO's are responsible for ensuring that LTPP owned equipment is properly maintained. Decisions required for proper maintenance and repair should be made based on testing schedule and expedited as necessary, to prevent disruption of testing.

Accidents: In event of an accident, operator will inform RCO of incident as soon as practical after mishap. Details of event shall subsequently be reported in writing to RCO.

3.3 FIELD TESTING

3.3.1 General Background

The following sequence of field work tasks and requirements provides an overall perspective of the typical work day at a test section.

Task 1: Personnel Coordination

- a: Dipstick® crew (operator and recorder)
- b: Traffic control crew supplied by state highway agency, or traffic control contractor working for the state agency (as recommended by state highway agency or provincial highway agency)
- c: Other LTPP, State DOT, and RCO Personnel (they are observers and are not required to be present)

Task 2: Site Inspection

- a: General pavement condition (within test section limits)
- b: Identify wheel paths

Task 3: Dipstick® Measurements

- a: Mark wheel paths
- b: Operational checks on Dipstick®
- c: Obtain Dipstick® measurements
- d: Quality control

Task 4 : Forms DS1 through DS7 should be completed for longitudinal profile measurements. For transverse profile measurements, forms DS7, Dipstick Field Activity Report - Transverse Profile, and Dipstick Transverse Profile Data Form should be completed.

On arrival at a site, operator will carefully plan activities to be conducted to insure most efficient utilization of time. While many activities can only be accomplished by operator and/or recorder, it will be necessary to enlist the assistance of other personnel at the site to mark wheel paths. In general, arrangements for this assistance should be made in advance.

Assuming that a manual distress survey is also to be performed at the site, traffic control typically should be available for six to eight hours. This should provide adequate time for Dipstick® measurements in both wheel paths as well as for the manual distress survey to be completed. Experienced Dipstick® operators can obtain approximately 500 readings/hour.

Collecting profile data is the primary responsibility of operator. In order to ensure that data collected in the four LTPP regions are identical in format, certain guidelines and standards have been established for data acquisition and handling.

3.3.2 Site Inspection and Layout - Longitudinal Profile Measurements

The pavement must be clear of ice, snow, and puddles of water before profile measurements can be taken with the Dipstick®, as such conditions can affect profile measurements. Pools of water can possibly damage electronics in the Dipstick® and must be avoided either through adjusting schedule of profiling trips, or by delaying actual measurements until acceptable conditions exist.

The longitudinal Dipstick® measurement procedure consists of performing an elevation survey in each wheel path, and using transverse measurements at the section ends to form a closed loop. As illustrated in figure 3.1, measurements start at Station 0+00 in the right wheel path and proceed in the direction of traffic toward end of section. At end of section, transverse measurements are made to the end point of survey line in left wheel path. A 0.61 m diameter closure circle around this point is used to close transverse measurements on this start location for measurements in the left wheel path. Longitudinal measurements are then performed in the left wheel path back to Station 0+00. Transverse measurements and closure circle are used to close the survey on the starting point. This procedure is designed for a 152.4 m test section; however, the concept can be applied to test sections of any length.

If acceptable conditions are present to perform the Dipstick® measurements, clean both wheel paths of loose stones and debris to prevent slippage of the Dipstick® footpads during measurements. The first step in the site layout is to locate the wheel paths, where each wheel path is located at a distance of 0.826 m from the center of travel lane. Use following procedure to locate center of travel lane;

> Case I: Where wheel paths are easily identified, midway point between two wheel paths should be used as center of lane.
>
> Case II: If wheel paths are not clearly identifiable, but two lane edges are well defined, center of travel lane is considered to be midway between two lane edges.
>
> Case III: Where wheel paths are not apparent and only one lane edge can be clearly distinguished, center of lane should be established at 1.83 m from that edge.

LTPP Manual for Profile Measurement, July 1997

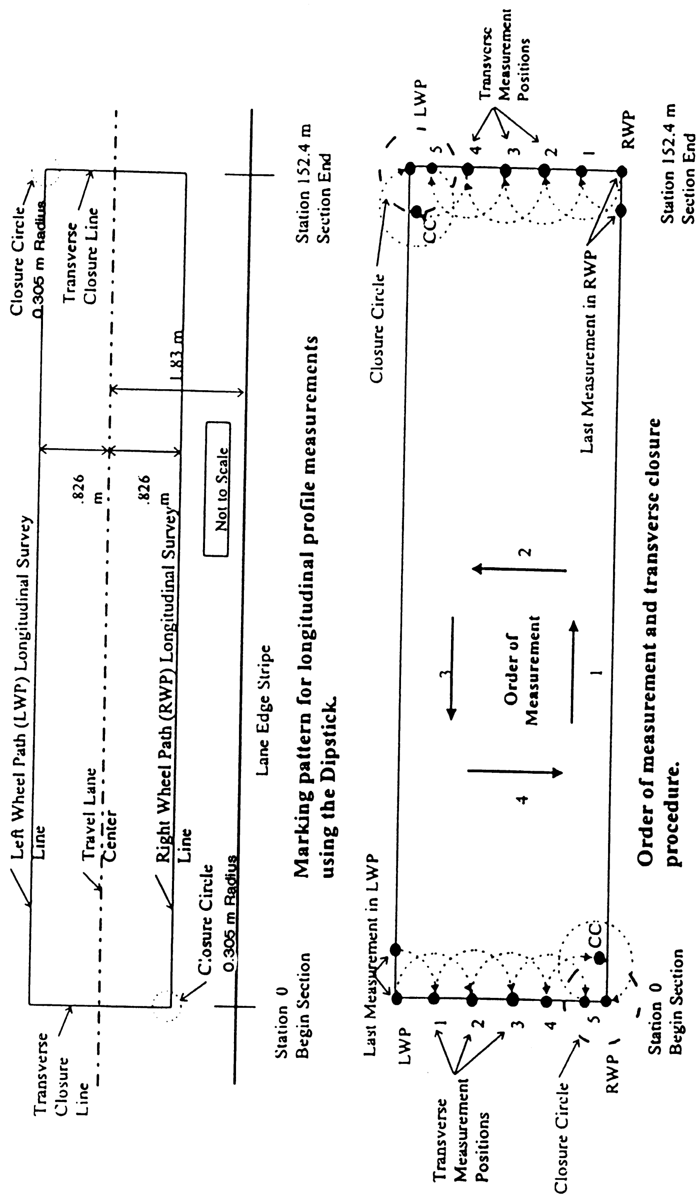

Figure 3.1 Longitudinal Profile Measurements with Dipstick - Site Layout and Measurement Procedure

3-6

Once center of travel lane has been identified, use following procedure to layout site:

1 Identify location of two longitudinal elevation survey lines 0.826 m from center of lane. Mark these locations at intervals equal to length of chalk line used for marking. Use chalk line to mark a straight line between previously established points. Start location should be located so that back edge of the Dipstick® footpad is located immediately adjacent to leave edge of white stripe at beginning of monitoring portion of test section. If this location is not marked with a stripe, the start location should be established at Station 0+00. Using a tape measure (measuring wheels are not acceptable), carefully measure length of each longitudinal elevation survey line to establish end points at 152.4 m, or at specified length for test sections that are not 152.4 m long, from the previously established start location. An accurate measurement of this length is required since it is used as a quality control check on the measurement process.

2. At Station 0+00 use a chalk line to mark a transverse line connecting the endpoints of the two longitudinal elevation survey lines. In right wheel path, mark a 0.61 m diameter circle centered on the first measurement point. This closure circle will be used for completion of elevation survey loop.

3. At end point marks placed at Station 152.4 m, or end of test section, use a chalk line to mark a transverse line connecting the endpoints of the longitudinal elevation survey lines. Mark a 0.61 m diameter circle centered on the measurement point located in the left wheel path at this location. This closure circle will be used for completion of elevation survey loop.

4. Note on data collection sheet or field notebook, method used to establish location of lane center and any discrepancies between painted and measured section end

locations. This information will help to collect consistent data in future profile measurements at that section.

3.3.3 Dipstick Operation for Longitudinal Profile Measurements

3.3.3.1 Pre-operational Checks on Dipstick

Checks to be performed on the Dipstick® prior to testing are described in this section.

1. Check condition of footpads and replace if necessary with extra set in the Dipstick® case. Clean and lubricate ball and socket joints on the footpads to insure smooth pivoting of instrument. When joint is dirty, pivoting becomes difficult and slippage of footpad can occur. A cleaning agent such as WD-40 or a light oil for lubrication will work for the ball and socket joint.

2. Install a fresh set of batteries in the instrument and securely close battery compartment. Batteries should be changed after 4 hours of usage to insure continuity of measurements. Several sets of rechargeable 9 Volt batteries should be kept on hand.

3. Check and if necessary, re-tighten handle on the instrument.

4. Perform Zero Check and Calibration Check, which are described next. According to manufacturer, calibration check is needed only if adjustments were required during the zero check. However, for LTPP related measurements, both the zero and calibration checks are required at the beginning of data collection. The Dipstick® should be fully assembled, turned on, and allowed to warm up for several minutes prior to performing these two checks.

Manual Dipstick (Model 1500)

Zero Check (Model 1500)

Form DS-7 included in Appendix II should be filled when this test is carried out. A zero verification is performed by this test. Test should be performed on a smooth, clean location where instrument can be properly positioned (carrying case for the Dipstick®, or a flat board will suffice). After positioning the Dipstick® draw two circles around footpads and note reading on display (reading = R1). The instrument should then be rotated 180 degrees and the footpads placed on the two circles which were drawn earlier; note reading obtained (reading = R2). If readings from the two placements (R1 and R2) add up to within ±0.1 mm, the Dipstick® has passed the zero check. If they do not fall within these limits, zero adjustment is necessary. The zero adjustment should be performed using the following procedure:

1. Obtain average of two Dipstick® readings; e = 0.5 (R1 + R2)

2. Subtract average value from R2 reading to obtain R2o; R2o = R2 - e

3. With Dipstick® still in R2 reading position, loosen the set screw and adjust start/end pin up or down so that display reads R2o.

4. Tighten set screw, rotate the Dipstick® back to R1 reading position and read display (reading = R1o).

5. Addition of R1o and R2o readings should be within tolerance; if not, repeat adjustment procedure until two readings are within tolerance.

This is the only adjustment operator is allowed to make on the Dipstick®.

Calibration Check (Model 1500)

Calibration of the Dipstick® is fixed during manufacturing and cannot be altered by the user. User can verify calibration against a standard calibration block which is provided with the Dipstick®. After zero check and adjustments are performed, calibration of device must be checked. Form DS-7 (see Appendix II) should be completed when this test is carried out. To check calibration, note the Dipstick® reading and place the 3.2 mm calibration block under one of the Dipstick® foot pads. The reading displayed minus 3.2 should be within ±0.1 mm of previous reading. If this tolerance is not obtained, a LTPP Major Maintenance/Repair Activity Report (see Appendix II) should be completed and Face Technologies should be contacted through RCO office to repair Dipstick®.

Automated Dipstick (Model 2000)

Zero Check (Model 2000)

This check should be performed on a smooth, clean and stable location (carrying case for the Dipstick® or a flat board will suffice) where the instrument can be properly positioned. Circles shall be drawn around the two footpads and the CAL button depressed once. The instrument should then be rotated 180 degrees and the two footpads placed in the circles drawn earlier. The CAL button should again be depressed once. The display will indicate "CAL" three times after which the error is automatically stripped out of the readings. No physical adjustments should be made. The zero check can only be performed once. If check is not successful, the Dipstick® must be turned off, turned back on, and the zero check repeated. A check mark should be placed on Form DS-7 (see Appendix II) at the appropriate location to indicate that the zero check was performed.

Calibration Check (Model 2000)

Follow procedure described for the manual Dipstick® (Model 1500) to perform this check. Form DS-7 (see Appendix II) should be completed when this test is carried out.

3.3.3.2 Longitudinal Profile Measurement

Complete header information on form DS-1 (See Appendix II). The following procedures should be followed to collect longitudinal profile data using the Dipstick®.

1. To start profile measurement, Dipstick® should be placed on marked survey line in RWP (right wheel path) at Station 0+00, with start arrow pointed forward in direction of traffic.

2. After reading stabilizes, it should be recorded under the right wheel path column on Form DS-2 (included in Appendix II) on the row corresponding to Reading Number 1. The Dipstick® should then be rotated to the next measuring point using a clockwise rotation. After reading has stabilized, it should be recorded on the next row of Form DS-2 labeled Reading Number 2. This procedure should be repeated for entire length of test section. During measurements, the following precautions and procedures should be followed:

   (a) Always use a clockwise rotation.
   (b) Handle of Dipstick® should be held in a vertical position when taking measurements.
   (c) Lateral pressure should not be applied to handle during a measurement.
   (d) Foot pads should be placed to avoid minor localized cracks, holes, open joints, edge of open joints or wide cracks.
   (e) If for any reason measurements must be stopped, circles should be drawn around both foot pads with the start arrow in the direction of traffic at last measurement position. When restarting, the Dipstick® shall be returned to this

position and adjusted so that current measurement agrees with the measurement prior to stoppage.

(f) If it is not possible to mark the leg positions prior to stoppage or to successfully reposition the Dipstick® in the same position, then data must be discarded and the measurement procedure restarted from the beginning.

3. After last measurement in right wheel path at Station 152.4 m, the location of the front Dipstick® foot should be compared to the pre-measured end point location. If front foot is within 152 mm of marked end point location, proceed with transverse closure measurements as indicated in step 4. If front foot is not within this interval, perform the following:

   (a) Draw circles around each foot and note direction of start arrow.
   (b) Check data sheets for skipped or missing measurements.
   (c) If no apparent anomalies are present in data, remeasure length of longitudinal survey line to verify position of end point. If re-measured location of end point is within 152 mm of front foot of the Dipstick®, remark transverse line at this location and proceed. If end-point is not within 152 mm of the Dipstick® front foot, discard data as suspect and restart survey from Station 0+00.

4. After location of last measurement in right wheel path has been verified, transverse closure measurements should be initiated by rotating rear foot of the Dipstick® toward left wheel path and placing it on pre-marked transverse closure line. Measurements along transverse closure line should be recorded in the table labeled "Transverse Closure Measurements from Right Wheel Path to Left Wheel Path at Station 152.4 m” located at the bottom of form DS-6 (included in Appendix II). When the Dipstick® reaches point in which next measurement along transverse survey line passes location of left wheel path, it should be rotated so that the foot

pad rests at any point on the closure circle (CC). After recording this measurement in the column labeled 5-CC, rotate device so that foot pad rests on top of intersection between the longitudinal survey line in the left wheel path and the transverse closure line. Record this measurement under CC-LWP. This procedure is illustrated in figure 3.1.

5. Begin measurements down longitudinal survey line in left wheel path, recording them in column labeled LWP on forms DS-6 through 2. These measurements will be entered in reverse order from those in RWP.

6. When last measurement in left wheel path is made at Station 0+00, verify that position of front Dipstick® foot is within 152 mm of end point. If not, follow procedures for end point verification previously discussed for the measurements in right wheel path. If a problem is found with a missing or skipped measurement or final location of Dipstick® in left wheel path, measurements in left wheel path should be discarded as suspect and survey restarted at beginning point in the left wheel path.

7. After location of last measurement in left wheel path has been verified, then closure measurements along transverse closure line back toward starting point in RWP should be performed. As illustrated in Figure 3.1, use closure circle made around starting point to close elevation survey on start point. Record these measurements in table located at bottom of form DS-2 (included in Appendix II).

3.3.3.3. Post Data Collection Check

After completing survey, operator must conduct the zero and calibration checks. For manual Dipstick® (Model 1500), obtain readings R1 and R2 as described in zero check in section 3.3.3.1. Readings from the two placements (R1 and R2) should add up to within $\pm$ 0.1 mm in order to pass the zero check. If the addition of the two readings is outside these limits, the device has failed the zero check. For automated Dipstick® (Model 2000), the zero check should be performed as described previously for the manual Dipstick® (Model 1500). For both manual Dipstick® (Model 1500) and automated Dipstick® (Model 2000), the calibration check should be performed as described in section 3.3.3.1 for the manual Dipstick®.

Results from these checks should be entered on Form DS-7 (see Appendix II). Based on results from these checks, follow one of the applicable procedures presented below:

1. If Dipstick® fails zero check the data should be discarded as suspect and another survey should be performed.

2. If Dipstick® passes zero check, but fails calibration check, data should be discarded as suspect and Face Technologies should be contacted for repair, as discussed under calibration check in section 3.3.3.1 of this manual.

3. If Dipstick® passes both tests, the closure error computations that are described in section 3.3.3.4 should be performed.

If Dipstick® failed zero check but can successfully be adjusted to pass zero cheek, and also passes the calibration check, another survey should be performed.

3.3.3.4 Closure Error Computations

The following procedures should be followed when performing closure error computations.

1. Closure error computations must be performed in the field prior to leaving site.

2. Readings in each column on forms DS-2 through 6 (see Appendix II) should be

summed and recorded in last row of each column. Measurements in transverse closure measurement tables on forms DS-2 and DS-6 (see Appendix II) should be summed across row and entered in last column.

3. Column summations should be entered onto form DS-1 (see Appendix II) in locations corresponding to labels shown in each summation cell.

4. On form DS-1 (see Appendix II), elevation sums in the RWP and LWP should be added together and recorded in indicated cells.

5. Transverse sums should then be added to each of these sums and the result recorded in the total row at bottom of closure calculation table.

6. Two totals should then be added together and the result entered into cell labeled closure error.

7. If closure error is not within ±76 mm, then data should be discarded as suspect and test section re-surveyed until closure error is within allowable limits.

3.3.4 Site Inspection and Layout - Transverse Profile Measurements

Pavement must be clear of ice, snow, and puddles of water before profile measurements can be taken with the Dipstick®, as such conditions can affect profile measurements. Pools of water can possibly damage electronics in the Dipstick® and must be avoided either through adjusting schedule of profiling trips, or by delaying actual measurements until acceptable conditions exist.

Layout and mark straight lines for transverse profile measurements. Lines shall be perpendicular to edge of pavement and located at 15.25 m intervals, starting at station 0 and ending at station 152.4 m (or end of section if length of test sections is different from 152.4 m). For GPS sections, eleven transverse lines will be present. Location of these lines should be adjusted to avoid raised pavement markings and similar anomalies. The need for and magnitude of such adjustments is to be recorded on appropriate data sheets. Transverse profile measurements should be performed when manual surveys are conducted on asphalt surfaced pavements. Transverse profile measurements are not required for rigid pavements.

3.3.5 Dipstick Operation for Transverse Profile Measurements

3.3.5.1 Pre-operational Checks on Dipstick

Operator should check equipment using procedures described in section 3.3.3.1. Checks will include both the zero check and the calibration checks. Operator should fill out a Dipstick Field Activity Report - Transverse Profile form (see Appendix II).

3.3.5.2 Transverse Profile Measurement

Dipstick® transverse profile measurements will be collected at 15.25 m intervals starting at station 0+00. Elevations for each transverse profile location will be measured from outside edge of pavement and should extend over full lane width, with actual distance depending on lane width and pavement striping. Starting point should be junction of transverse measurement line and inside edge of white paint stripe along outside edge of the lane. If no outside edge stripe is present, then beginning point shall be either shoulder-lane joint or a point approximately 0.91 m from center of outside wheel path. A comment should be entered in the data sheet commenting on how starting point was determined. The initial elevation is arbitrarily established as “zero” and subsequent readings are recorded relative to this benchmark. The combination of these measurements provide a measure of pavement cross slope.

To begin transverse profile measurements, Dipstick® is placed at outside edge of pavement starting at Station 0+00 with start arrow pointed towards pavement center line.

Measurements should be recorded on the Transverse Profile Data Collection Form (see Appendix II). Operator should complete two runs per transverse profile of each LTPP section; one run up the transverse line and a return along same line to complete closed loop survey.

3.3.5.3 Post Data Collection Check

After completing survey, operator must conduct zero and calibration checks. For manual Dipstick® (Model 1500) obtain readings R1 and R2 as described in zero check in section 3.3.3.1. Readings from two placements (R1 and R2) should add up to within ± 0.1 mm. to pass the zero check. If the addition of the two readings is outside this limit, the device has failed the zero check. For automated Dipstick® (Model 2000), this check should also be performed as described previously for the Manual Dipstick® (Model 1500). For both manual (Model 1500) and automated Dipsticks® (Model 2000), the calibration check should be performed as described in section 3.3.3.1.

Results of these checks should be entered on Form DS-7 (see Appendix II). Based on results from these checks, follow one of the applicable procedures presented below:

1. If Dipstick® fails zero check then data should be discarded as suspect.
2. If Dipstick® passes zero check, but fails calibration check, data should be discarded as suspect and Face Technologies should be contacted for repair, as discussed under calibration check in section 3.3.3.1 of this manual.
3. If Dipstick® passes both tests, the closure error computations that are described in section 3.3.5.4 should be performed.

If Dipstick® failed zero check but can successfully be adjusted to pass zero check, and also passes calibration check, another survey should be performed.

3.3.5.4 Closure Error Computation

The total accumulated error in a transverse profile is established by a closed loop survey. The forward and return run along a transverse line is utilized to compute this error. For each transverse profile, sum the Dipstick® readings for the forward and return runs to obtain the closure error. To compute the allowable closure error for a transverse profile run, multiply total number of Dipstick® readings (sum of readings for forward and return run) by 0.076 (0.076 mm is allowable average error per one Dipstick® reading). The allowable closure error for typical lane widths that are encountered are given in table 3.1 If the closure error for a transverse profile is outside the allowable range, those data should be discarded and measurement of the transverse profile repeated.

Table 3.1. Allowable closure errors for transverse Dipstick® measurements

Lane Width (m)	Total Number of Dipstick Readings	Allowable Closure Error (mm)
3.05	20	+/-1.5
3.35	22	+/-1.7
3.66	24	+/-1.8
3.96	26	+/-2.0

3.3.6 Data Backup

The importance of safeguarding Dipstick® data cannot be overstated. Back-up copies of the Dipstick® data must be made without exception after completion of data collection at the earliest time possible.

A minimum of two complete copies shall be made of all Dipstick® data. One copy will be transmitted by mail to the regional coordination office while the second will be retained by operator in case first copy is lost in mail.

3.4 CALIBRATION

3.4.1 General Background

To ensure that the Dipstick® is operating properly, the calibration can be checked using the zero and calibration checks described in section 3.3.3.1. If Dipstick® fails calibration test it should be returned to manufacturer for repair.

Gauge block used during calibration check should be calibrated to an accuracy of 3.18 $\pm$ 0.03 mm using a local calibration laboratory or a calibration micrometer to ensure minimum 4:1 ratio of accuracy of gage blocks to Dipstick®. Gage block should be recalibrated once every year, or more frequently, depending on (1) presence of oxidation, (2) evidence of erosion, and (3) possible damage caused by accidental mishandling in field.

If calibration block (gauge block) thickness is not within 3.18 $\pm$ 0.03 mm all data collected since last check of block are suspect and may have to be disregarded.

3.4.2 Calibration Frequency

The zero and calibration checks should be conducted by operator prior to and after any Dipstick® measurements. Procedures for performing pre-operational zero check and calibration check are described in section 3.3.3.1. Procedures for performing post-operational zero check and calibration check are described in section 3.3.3.3. If Dipstick® fails calibration test, approval from an RCO engineer is required before shipping equipment to manufacturer.

3.5 EQUIPMENT MAINTENANCE AND REPAIR

3.5.1. General Background

Scheduled preventive maintenance will serve as a means of ensuring proper operation of equipment, as well as, identifying potential problems. Timely identification of problems will help to avoid costly delays or incomplete data which could result from on site equipment malfunction. Time constraints on the profile testing program require that maintenance activities be performed prior to mobilization for testing. During testing, it is necessary that operator be constantly aware of proper functioning of equipment. There will be little time to accomplish more than the required initial checks at site in preparation for test day. Therefore, there is a paramount need for preventive maintenance to be performed as a routine function at the end of each test/travel day and on days when no other work is scheduled.

Minimizing rate of equipment deterioration is the responsibility of the RCO and individual operators. Specific, detailed maintenance procedures are contained in the manuals provided with each individual piece of equipment, and operator must become intimately familiar with the maintenance recommendations contained in these manuals. This section is intended to reinforce the concept of maximum equipment dependability, which is critical to the effectiveness of the LTPP program.

It is not the intention of this guide to supersede manufacturers' minimum services and service intervals, but to provide supplementary service requirements. Where there is a conflict between this guide and the manufacturers' instructions, the more stringent requirements should be followed.

3.5.2 Routine Maintenance

Routine maintenance includes those functions which can be easily performed by operator with minimal disassembly of the device. Routine maintenance for the Dipstick® include cleaning and lubrication of ball and socket joints on footpads, replacement of batteries and cleaning of battery contacts. These items are basic and easily performed preventive measures and should always be completed prior to operation of equipment.

The following list of pre-operation preventive maintenance items is not complete, but is intended to show the extent and detail required before operation checks are performed. This list of items is not to supersede manufacturers' minimum requirements for warranty compliance.

1. Exterior: Check general appearance, glass display (should be clean), ball and socket joint for footpads (should be properly lubricated).

2. Accessories: Be sure adequate supplies of consumables are on hand (e.g., Batteries, grease, WD-40).

3.5.3 Scheduled Major Maintenance

Scheduled major preventive services shall include much more than routine checks and will require some disassembly of equipment by personnel with technical capabilities beyond skill of operators or ROC staff. The LTPP Major Maintenance/Repair Report (see Appendix II) should be used by operator to report performance of necessary services. This form will also serve to inform RCO of condition of Dipstick® on a regular basis. Items such as battery connector replacement would fall into the major maintenance category. Appropriate service intervals are outlined in the equipment manufacturer’s manual.

3.5.4 Equipment Problems/Repairs

Regardless of the quality of the preventive program, there will probably be equipment failures during the LTPP program. When these occur, it is extremely important that repairs or replacement of items be accomplished in a timely fashion. During periods when there is no scheduled testing, these problems are easily handled. However, if they occur during mobilization or while on-site, significant problems in scheduling and coordination could develop. To help minimize impact of equipment problems, it is essential that operator immediately notify RCO and any other agencies or individuals as necessary.

Responsibility for equipment maintenance/repair activity rests with each RCO. However, ROC should keep LTPP staff informed of any major problems concerning equipment. When repairs are necessary and must be performed by an outside agency, operator will report this information on the LTPP Major Maintenance Report form as an unscheduled maintenance activity. Details of circumstances during field testing related to this maintenance activity should be noted on appropriate data sheets.

3.6 RECORD KEEPING

Dipstick® operator will be responsible for maintaining the following Forms/Records.

1. For Longitudinal Profile Measurements: Longitudinal Profile Form DS-1
2. For Transverse Profile Measurements: Dipstick Field Activity Report - Transverse Profile
3. Zero and Calibration Check Records (form DS-7) for both longitudinal and transverse profile measurements
4. Major Maintenance/Repair Report

All these forms are included in Appendix II. Each of these records shall be kept in up-to-date files by each RCO with one complete set kept on file at the regional office. A description of each of these forms follows.

3.6.1 Longitudinal Profile Measurement Form DS-1

This form should be filled at every section where longitudinal profile measurements are performed with a Dipstick®. Comments section in this form should include any downtime and any factors which might affect collected test data. Names and organizations of other personnel present at site should be included in this form. Names of these personnel will be invaluable if an accident occurs at test site. A space is provided in this form for operator's acknowledgment that pre-operation checks were conducted prior to any Dipstick® testing. Original of this report should be kept by operator with a copy forwarded to RCO.

3.6.2 Dipstick Field Activity Report - Transverse Profile (Form DS-8)

This form should be filled at every section where transverse profile measurements are performed with a Dipstick®. Comments section in this form should include any downtime and any factors which might affect collected test data. Names and organizations of other personnel present at site should be included in this form. Names of these personnel will be invaluable if an accident occurs at test site. A space is provided in this form for operator's acknowledgment that pre-operation checks were conducted prior to any Dipstick® testing. Original of this report should be kept by operator with a copy forwarded to RCO.

3.6.3 Zero and Calibration Check Form (Form DS-7)

This form should be completed whenever the zero and calibration checks are carried out.

3.6.4 LTPP Major Maintenance/Repair Report

When any major maintenance or repair must be performed by an outside agency, the LTPP Major Maintenance/Repair Activity Report (see Appendix II) must be completed.

4. PROFILE MEASUREMENTS USING THE ROD AND LEVEL

4.1 INTRODUCTION

The rod and level can be used to accurately measure profile of a pavement. This data can be used to evaluate roughness of pavement by computing a roughness index such as the International Roughness Index (IRI). In computing roughness indices, only relative elevations and not absolute elevations are needed. The guidelines in this section can be applied to conventional survey equipment such as an optical level and graduated staff which require readings to be manually recorded as well as automated equipment which are capable of automatically storing measured data.

4.2 OPERATIONAL GUIDELINES

4.2.1 General Procedures

Detailed scheduling and traffic control at test sites must be coordinated by RCO. However, all traffic control activities at test sites will be performed by personnel from either the state or provincial highway agency. Layout of test site should not be undertaken until all applicable traffic control devices are in-place.

4.2.2 Equipment Requirements

The rod and level used in routine surveying and road construction will generally not have resolution needed for pavement profile measurements. For pavement profile measurements, precision leveling instruments are required. Instrument used for profile measurement should satisfy resolution criteria given in the following table, which was obtained from the ASTM Standard on Measuring Road Roughness by Static Level. (9)

IRI Range (m/km)				Resolution (mm)
0	<=	IRI	<0.5	0.125
0.5	<=	IRI	<1.0	0.25
1.0	<=	IRI	<3.0	0.50
3.0	<=	IRI	<5.0	1.0
5.0	<=	IRI	<7.0	1.5
		IRI	>7.0	2.0

Rod used should be equipped with a bubble level so that it can be accurately held vertically. A suitable base must be selected for rod in order to reduce sensitivity to small variations in rod placement. For smooth textured pavements, any type of base is suitable. For textured surfaces a circular pad with a diameter of at least 20 mm is recommended. [9] As only relative elevations are required for computing roughness indices, no correction is required for attaching a pad to bottom of rod.

4.2.3 LTPP Procedures

Maintenance of Records: Operator is responsible for forwarding all data collected during testing to the RCO.

Accidents: In event of an accident, operator will inform RCO of incident as soon as practical after mishap. Details of event shall subsequently be reported in writing to RCO to assist in any insurance claim procedures.

4.3 FIELD TESTING

4.3.1 General Background

The following sequence of field work tasks are required.

Task 1: Personnel Coordination

- a: Personnel for rod and level survey.

b: Traffic control crew supplied by state or provincial highway agency or traffic control contractor working for state agency (as recommended by state or provincial highway agency)

c: Other LTPP, State DOT, and RCO personnel (they are observers and are not required to be present)

Task 2: Site Inspection

a: General pavement condition (within test section limits)

b: Identify wheel paths

Task 3: Rod and Level measurements

a: Mark wheel paths

b: Obtain rod and level readings

To measure pavement profile using rod and level, two persons are needed. One person is needed to hold rod (rod-person) and another to operate level and take readings (instrument operator). If level is not capable of automatically recording readings, having an additional person (record keeper) to record readings will make the process quicker.

According to ASTM Standard on Measuring Road Roughness by Static Level(9), an experienced crew of three would require less than 10 seconds to obtain one reading. This involves positioning of rod by rod-person, reading level by instrument operator and recording of measurements by record keeper.

4.3.2 Site Inspection and Preparation

The two wheel paths in the outside travel lane should be marked using the following procedure.

1. Clean area of both wheel paths of loose stones and debris to prevent slippage of rod during measurements.

2. Use chalk line to mark straight line in each wheel path, which should be 0.826 m from center of travel lane. Center of travel lane should be located using the following guidelines.

   Case I: Where wheel paths are easily identified, midway point between two wheel paths should be used as center of lane.

   Case II: If wheel paths are not clearly identifiable, but two lane edges are well defined, center of travel lane is considered to be midway between two lane edges.

   Case III: Where wheel paths are not apparent and only one lane edge can be clearly distinguished, center of lane should be established at 1.83 m from that edge.

The method by which wheel paths were located should be noted in the comments field of the Field Form for Rod and Level (see Appendix III). This will help in locating wheel paths used for profile measurements at a future date.

Measurements have to be taken along wheel paths at 0.3 m intervals. Locations at which readings are to be taken can be determined by either of the following methods:

1. Lay surveyor's tape along chalk line and mark distances on pavement at 0.3 m intervals using a suitable marker. Markings have to be made along entire length of section on both wheel paths.

2. Place surveyor's tape on wheel path with the zero mark of tape directly on start of section. Station zero is the leave edge of the white stripe at the beginning of the test section. Secure both ends of tape with adhesive tape. Distances along section can be referenced from the tape. After distance corresponding to length of tape is leveled, tape will have to be repositioned.

4.3.3 Longitudinal Profile Measurements

The first reading taken after level is set-up is referred to as a backsight, while last reading taken at that setup before level is moved is referred to as a foresight. Other readings taken in-between a backsight and a foresight are referred to as intermediate sights. The procedure to be followed for measuring longitudinal profile is described next.

1. Complete required information in the Rod and Level Data Collection Form (Appendix III).

2. Set up level at a suitable location taking into account range of level. With some instruments, it might be possible to cover entire test length from one instrument set up, located near center of test section. Level should be setup at a position where it will not be disturbed due to passing traffic. In addition, it should be setup at a stable location which will not settle. When setting tripod, set it as low as practical to reduce error caused by rod not being held exactly vertical. Thereafter, level instrument using leveling screws.

3. Rod-person should place rod at zero position of section and using bubble level attached to rod as a reference, hold rod vertically. Once rod is held vertically rod-person should signal to instrument operator to take a reading. If readings are recorded manually by a third crew member, instrument operator should call out reading to record-keeper. Readings should be recorded in the form shown in

Appendix III. If an automated system is being used, instrument operator should make sure that reading is saved.

4 Next, rod-person should place rod 0.3 m away from initial reading, and a new reading should be recorded. This process should be continued until either entire test section is surveyed or horizontal range or vertical range of level is exceeded. Horizontal range of level is exceeded if distance between level and rod is too short or too long to focus properly. Vertical range of level is exceeded if rod cannot be read due to slope of the road. When range of the level is exceeded, level has to be relocated.

5. (a) Range of Level is Exceeded:

If range of level is exceeded, instrument has to be relocated. Mark location at which rod is to be held for last reading. This position is called a pivot point. Thereafter, place rod at location where first reading was taken with current setup of level, and take a reading. Compare this reading with first reading that was taken at this location. If they do not agree within resolution of instrument, all readings taken from the current level position have to be repeated. If readings agree, place rod on pivot point and take last reading from current set up of instrument (foresight). Then set up instrument at new location. Place rod at pivot point and take reading (backsight). Continue leveling process as before, taking readings at 0.3 m intervals. If instrument has to be repositioned again, follow procedure described earlier.

(b) End of Test Section is Reached: The following two cases are possible.

1. Entire Survey Performed from One Instrument Set Up: Place rod at zero position (point from which survey was initially started) and take a reading. This reading should agree with first reading taken at this location at start of the

survey within resolution of instrument. If readings do not agree, profile measurement has to be repeated.

2. Instrument Repositioned During Survey: Place rod at last pivot point and take a reading. This reading has to agree with earlier reading taken at this position within resolution of instrument. If they do not agree, profile has to be measured again from last pivot point to end of section.

Measurement of pavement profiles using rod and level is labor intensive, and time consuming. Therefore, it is advisable to check accuracy of measured data at regular intervals. This can be performed by establishing a set of control points along wheel path, for example at 30 m intervals starting from beginning of section. After leveling a distance of 30 m, rod has to be placed at previous control point and another reading taken. This reading has to agree with previous reading taken at this control point within resolution of instrument. If readings do not agree, the distance between control points has to be measured again. This procedure can be used if instrument set up is not changed between two control points being considered. If instrument set up is changed between two control points, above procedure can still be applied by treating pivot point as a control point.

4.3.4 Factors to be Considered

The following factors have to be considered when conducting profile measurements with rod and level.

1. If level is sensitive to temperature variations, it might need to be covered with an umbrella to protect it from direct sunlight.
2. During windy conditions profile measurements should be avoided, as movement of level could occur.

3. If level has to be set up at more than one position during profile measurements, make length to backsights and foresights equal. This will eliminate errors due to curvature and re refraction at turning points.
4. Set up level as low as possible to reduce error caused by the rod being not exactly vertical.

4.3.5 Profile Computation

In the field, during profile measurements, the crew is only expected to record readings of level using procedures described in section 4.3.3. Computation of elevation profile from these data will be done in the office. This section briefly describes how data recorded in field is used to obtain longitudinal profile of pavement.

For profile computations, elevation of location where first reading (first backsight) was measured is needed. However, as only relative elevations are needed to compute roughness indices (such as IRI), an arbitrary value can be selected for the elevation of this point. Relative elevation of any point measured from initial instrument set up can be obtained from the following equations:

Instrument Height (IS) = BM + RR1 ....(4.1)

Relative Elevation of a Point = IS - RR ....(4.2)

where,

IS =	Initial Instrument Height
BM =	Elevation of point where first backsight was taken (assume any value e.g. 30 m)
RR1=	Rod Reading at first backsight
RR =	Rod reading at any point from initial instrument setup

Once position of level is changed, instrument height will also change. New instrument height can be obtained from the following equation.

Nht = Oht + BS - FS ....(4.3)

where,

Nht = New instrument height

Oht = Old instrument height

BS = Backsight at pivot point

FS = Foresight at pivot point

Relative elevation of points measured from this new instrument location can be determined by using Equation 4.2 and using new instrument height.

4.3.6 Quality Control

Field Quality Control: This check ensures that no movement of level took place during current setup of level. This has to be verified every time before instrument is moved and when end of test section is reached. This check is performed by keeping rod at location at which first reading was taken with current instrument setup and again taking a reading. Both readings have to agree within resolution of instrument. This check can also be performed at regular intervals by establishing a set of control points as described in section 4.3.3.

4.4 CALIBRATION AND ADJUSTMENTS

The user manual of the level should be consulted on how to perform adjustments to instrument. Different makes/models of levels will require different adjustments to be performed. The following are some common adjustments which are required in levels in order to obtain accurate measurements. The user manual should be consulted to determine if the following adjustments are needed for level being used and, if so, how to perform the specific adjustment.

1. Make Axis of Level Bubble Perpendicular to Vertical Axis: After setting up level, center bubble. Move telescope 180 degrees about vertical axis. If bubble moves, instrument needs adjustment.

2. Adjust Horizontal Cross Hairs: This adjustment will ensure that horizontal cross hairs are truly horizontal when instrument is leveled.

3. Adjust Line of Sight : This adjustment will make axis of sight perpendicular to vertical axis and also make it parallel to axis of level. The method of adjustment for this error is commonly referred to as the two-peg method.

Rod has to be checked to verify accuracy of markings. A standardized tape should be used for this.

4.5 EQUIPMENT MAINTENANCE

Shock proof packaging should be used when transporting instrument. After completing a profile measurement, always clean instrument. Before cleaning lenses, blow dust off lenses, then clean lenses using a soft cloth. Lenses should not be touched with fingers. If instrument becomes wet in field, make sure that it is completely dry before packing. Tripod should be inspected regularly to ensure that connections are not loose.

4.6 RECORD KEEPING

The Rod and Level Data Collection Form (see Appendix III) should be used to record readings when profile measurements are performed using rod and level. In addition, a comment should be made on this form as to how wheel paths were located. All items in this form should be completed by record-keeper. Even when an automated instrument which is capable of saving data is used, location information in this form should be completed.

5. REFERENCES

1. T-6600 Inertial Profilometer Hardware, Introduction/Setup/Road Testing, System Manual, R-41389, K.J. Law Engineers, Inc, February 1996.

2. T-6600 Inertial Profilometer Hardware, Cal/Utilities/File Format, System Manual, R-41389, K.J. Law Engineers, Inc, February 1996.

3. T-6600 Inertial Profilometer, System Manual, K.J. Law Engineers, Inc, February 1996.

4. Ford E-350 Vehicle Manual.

5. Dipstick Model 1500 and Model 2000 Manual, Face Technologies.

6. PROQUAL V2.08 Users Documentation, Report No. FHWA-TS-98-00-01, ITX Stanley Limited, Amherst, New York, June 1998.

7. Distress Identification Manual for the Long-Term pavement Performance Project. SHRP-P-338, Strategic Highway Research Program, National Research Council, Washington, D.C., 1993.

9. Manual for Profile Measurement: Operational Field Guidelines, SHRP-P-378, Strategic Highway Research Program, National Research Council, Washington, D.C., 1994.

8. Standard Test Method for Measuring Road Roughness by Static Level Method, Designation E 1364-90, American Society of Testing and Materials.

APPENDIX I

STANDARD FORMS FOR K.J. LAW PROFILOMETER®

DAILY CHECK LIST

ITEM
Under Hood
Fluids
Engine Oil
Brake
Windshield Washer Fluid
Radiator Coolant
Transmission
Exterior
Lights
Front
Rear
Emergency
Turning Signals
Beacon
Flashers
Glass Cleaning
Windshield
Displacement Sensor
Photo Cell
Underbody
Tires Properly Inflated
Fluid Leaks
Interior
Temperature Range

LTPP Profilometer Operations LTPP Profilometer Field Activity Report Form PROF-1	State Code [_ _] LTPP Section ID [_ _ _ _] Date (dd/mmm/yy) [_ _/_ _ _ /__]

File Name: ______________ **Testing:** ___________________ **District:** _____________

LTPP Experiment Code: _____________ **Route/Highway Number:** _____________

Testing Date: __________________________ **Sheet Number:** ___________________

Profilometer Vehicle Before Operation Checks:_______ (initial)

	Time	**Odometer**
Start Travel	___________	_____________
Begin Test	___________	_____________
End Test	___________	_____________
End Travel	___________	_____________

Down Time: _________Hours **Reasons:** ___________________________
_ ____

Number of Test:	**IRI Reading**
1	__________
2	__________
3	__________
4	__________
5	__________
6	__________
7	__________
8	__________
9	__________

Additional Remarks Regarding Testing: ____________________________________
____
____
____
____
_

Profile Crew: Driver:________________ **Operator:** ________________

Others Present (List names and agencies) ______________________________

LTPP Profilometer Operations
Status of Regions Test Sections
Form PROF-2

LTPP ID Number	Expt. Type (e.g., GPS)	Highway	Paint Marks	Delineators	Signs	Any Rehab Maint. ?	Date	Operator	Comments

LTPP Profilometer Operations
Profilometer Log
Form PROF-3

Date	Noted Problem	Action Taken and Date

LTPP Profilometer Operations
LTPP Major Maintenance/Repair Activity Report
Form PROF-4

Region: ________________________________ **Date:** ______________________________

Equipment ID

Make: __________________ **Model:** _________________ **S/N:** _______________

Odometer: ________________________________ (where applicable)

Reason for Maintenance Work (Choose only one)

Scheduled: ________ **Not Scheduled:** ________ **Routine:** ________

Description Of Maintenance And Reason: ____

____

____

____

____

Agency Performing Maintenance: **Cost:** ________________

Name: ____

Street: ____

City: _________________________________ **State:** _________ **Zip:** __________

Phone Number: ____

Contact Name: ____

Date In: ____

Date Out: ____

LTPP Profilometer Operations
Infrared Sensor Calibration Log
Form PROF-5

Date	Time	Location	Sensor	Base Height (mm)	Block Height During Calibration (mm)			Comments
					25 mm Block	50 mm Block	75 mm Block	
			Left					
			Center					
			Right					
			Left					
			Center					
			Right					
			Left					
			Center					
			Right					
			Left					
			Center					
			Right					
			Left					
			Center					
			Right					
			Left					
			Center					
			Right					
			Left					
			Center					
			Right					
			Left					
			Center					
			Right					
			Left					
			Center					
			Right					
			Left					
			Center					
			Right					
			Left					
			Center					
			Right					

APPENDIX II

STANDARD FORMS FOR DIPSTICKâ MEASUREMENTS

LTPP Dipstick Data Collection Form Longitudinal Profile Form DS-1 Measurement Information and Closure Computation	State Code [__ __] LTPP Section [__ __ __ __] Date (dd/mmm/yy) __ __ / __ __ __ / __ __

Operator: ________________________________ Employer: ______________________________

Recorder: ________________________________ Employer: ______________________________

Dipstick Serial Number: ____________________

Start Time (military): __ __ : __ __ Stop Time (military): __ __ : __ __

Weather: ____

Closure Error Computation

Right Wheel Path		Left Wheel Path		
No	Elevation Sum	No	Elevation Sum	
O1		I1		
O2		I2		
O3		I3		**Traffic Control Crew:**
O4		I4		
O5		I5		
O6		I6		
O7		I7		
O8		I8		
O9		I9		
O10		I10		
O11		I11		
O12		I12		
O13		I13		**Other Personnel At Site:**
O14		I14		
O15		I15		
O16		I16		
O17		I17		
O18		I18		
O19		I19		
O20		I20		
Total O1 to O20	OA	Total I1 to I20	IA	
Transverse Sum T2	OB	Transverse Sum T1	IB	**Closure Error**
Total OA+OB	OC	Total IA + IB	IC	OC+IC

LTPP Dipstick Data Collection Form Longitudinal Profile Form DS-2 Reading 1 to 100	State Code [__ __] LTPP Section ID [__ __ __ __] Date (dd/mmm/yy) [__ __ / __ __ __ / __ __]

Reading No.	Reading (mm)		Reading No.	Reading (mm)		Reading No.	Reading (mm)		Reading No.	Reading (mm.)	
	RWP ⇓	LWP ⇑		RWP ⇓	LWP ⇑		RWP ⇓	LWP ⇑		RWP ⇓	LWP ⇑
1			26			51			76		
2			27			52			77		
3			28			53			78		
4			29			54			79		
5			30			55			80		
6			31			56			81		
7			32			57			82		
8			33			58			83		
9			34			59			84		
10			35			60			85		
11			36			61			86		
12			37			62			87		
13			38			63			88		
14			39			64			89		
15			40			65			90		
16			41			66			91		
17			42			67			92		
18			43			68			93		
19			44			69			94		
20			45			70			95		
21			46			71			96		
22			47			72			97		
23			48			73			98		
24			49			74			99		
25			50			75			100		
Sum	O1	I1		O2	I2		O3	I3		O4	I4

Transverse Closure Measurements from Left Wheel Path to Right Wheel Path at Station 0+00

	Transverse Position							Sum
	LWP-1	1-2	2-3	3-4	4-5	5 - CC	CC - RWP	
Reading (mm)								T1

LTPP Dipstick Data Collection Form Longitudinal Profile Form DS-3 Reading 101 to 200	State Code [__ __] LTPP Section ID [__ __ __ __] Date (dd/mmm/yy) [__ __ / __ __ __ / __ __]

Reading No	Reading (mm)		Reading No	Reading (mm)		Reading No	Reading (mm)		Reading No	Reading (mm)	
	RWP ⇓	LWP ⇑		RWP ⇓	LWP ⇑		RWP ⇓	LWP ⇑		RWP ⇓	LWP ⇑
101			126			151			176		
102			127			152			177		
103			128			153			178		
104			129			154			179		
105			130			155			180		
106			131			156			181		
107			132			157			182		
108			133			158			183		
109			134			159			184		
110			135			160			185		
111			136			161			186		
112			137			162			187		
113			138			163			188		
114			139			164			189		
115			140			165			190		
116			141			166			191		
117			142			167			192		
118			143			168			193		
119			144			169			194		
120			145			170			195		
121			146			171			196		
122			147			172			197		
123			148			173			198		
124			149			174			199		
125			150			175			200		
Sum	O5	I5		O6	I6		O7	I7		O8	I8

LTPP Dipstick Data Collection Form Longitudinal Profile Form DS-4 Readings 201 to 300	State Code [__ __] LTPP Section ID [__ __ __ __] Date (dd/mmm/yy) [__ __ / __ __ __ / __ __]

Reading No.	Reading (mm)		Reading No.	Reading (mm)		Reading No.	Reading (mm)		Reading No.	Reading (mm)	
	RWP ⇓	LWP ⇑		RWP ⇓	LWP ⇑		RWP ⇓	LWP ⇑		RWP ⇓	LWP ⇑
201			226			251			276		
202			227			252			277		
203			228			253			278		
204			229			254			279		
205			230			255			280		
206			231			256			281		
207			232			257			282		
208			233			258			283		
209			234			259			284		
210			235			260			285		
211			236			261			286		
212			237			262			287		
213			238			263			288		
214			239			264			289		
215			240			265			290		
216			241			266			291		
217			242			267			292		
218			243			268			293		
219			244			269			294		
220			245			270			295		
221			246			271			296		
222			247			272			297		
223			248			273			298		
224			249			274			299		
225			250			275			300		
Sum	O9	I9		O10	I10		O11	I11		O12	I12

LTPP Dipstick Data Collection Form Longitudinal Profile Form DS-5 Readings 301 to 400	State Code [__ __] LTPP Section ID [__ __ __ __] Date (dd/mmm/yy) [__ __ / __ __ __ / __ __]

Reading No.	Reading (mm)		Reading No	Reading (mm)		Reading No	Reading (mm)		Reading No.	Reading (mm)	
	RWP ⇓	LWP ⇑		RWP ⇓	LWP ⇑		RWP ⇓	LWP ⇑		RWP ⇓	LWP ⇑
301			326			351			376		
302			327			352			377		
303			328			353			378		
304			329			354			379		
305			330			355			380		
306			331			356			381		
307			332			357			382		
308			333			358			383		
309			334			359			384		
310			335			360			385		
311			336			361			386		
312			337			362			387		
313			338			363			388		
314			339			364			389		
315			340			365			390		
316			341			366			391		
317			342			367			392		
318			343			368			393		
319			344			369			394		
320			345			370			395		
321			346			371			396		
322			347			372			397		
323			348			373			398		
324			349			374			399		
325			350			375			400		
Sum	O13	I13		O14	I14		O15	I15		O16	I16

LTPP Manual Dipstick Data Collection Form Longitudinal Profile Form DS-6 Station 401 to 500	State Code [__ __] LTPP Section ID [__ __ __ __] Date (dd/mmm/yy) [__ __ / __ __ __ / __ __]

Reading No	Reading (mm)		Reading No	Reading (mm)		Reading No	Reading (mm)		Reading No	Reading (mm)	
	RWP ⇓	LWP ⇑		RWP ⇓	LWP ⇑		RWP ⇓	LWP ⇑		RWP ⇓	LWP ⇑
401			426			451			476		
402			427			452			477		
403			428			453			478		
404			429			454			479		
405			430			455			480		
406			431			456			481		
407			432			457			482		
408			433			458			483		
409			434			459			484		
410			435			460			485		
411			436			461			486		
412			437			462			487		
413			438			463			488		
414			439			464			489		
415			440			465			490		
416			441			466			491		
417			442			467			492		
418			443			468			493		
419			444			469			494		
420			445			470			495		
421			446			471			496		
422			447			472			497		
423			448			473			498		
424			449			474			499		
425			450			475			500		
Sum	O17	I17		O18	I18		O19	I19		O20	I20

Transverse Closure Measurements from Right Wheel Path to Left Wheel Path at Station (152.40 m)

	Transverse Position							Sum
	RWP-1	1-2	2-3	3-4	4-5	5 - CC	CC -LWP	
Reading (mm)								T2

LTPP Dipstick Data Collection Form Longitudinal Profile Form DS-7 Pre/Post Measurement Zero and Calibration Checks	State Code [__ __] LTPP Section ID [__ __ __ __] Date (dd/mmm/yy) [__ __ / __ __ __ / __ __]

Operator: ___________________________________ Employer: ___________________________________

Dipstick Serial Number: _____________________ Diameter of Dipstick Foot Pad: __ . __ __ mm

Pre Measurement Checks

Time (military): __ __ : __ __ **Automated Dipstick** - Zero Check Performed:________________

Zero Check - Manual Dipstick		Calibration Check	
Measurement	Reading (mm)	Measurement	Reading (mm)
First Reading		First Reading	
Second Reading after 180° Rotation		Second Reading on Calibration Block	
First + Second Reading	A	Second Reading - 3.2 - First Reading	B

Notes:

A. First + Second Reading must be less than ± 0.1. If not, adjust the start pin as suggested in the LTPP Profile Measurement Manual and repeat zero check.

B. Second Reading - 3.2 - First Reading must be less than ± 0.1. If not, notify the RCOC office and contact Face Technologies for repair.

Post Measurement Checks

Time (military): __ __ : __ __

Zero Check		Calibration Check	
Measurement	Reading (mm)	Measurement	Reading (mm)
First Reading		First Reading	
Second Reading after 180° Rotation		Second Reading on Calibration Block	
First + Second Reading	A	Second Reading - 3.2 - First Reading	B

Notes:

A. First + Second Reading must be less than ± 0.1. If not, discard data as suspect, adjust the start pin as suggested in the LTPP Profile Measurement Manual, repeat zero check until it passes, perform calibration check and if it passes, resurvey section.

B. Second Reading - 3.2 - First Reading must be less than ± 0.1. If not, notify the RCOC office and contact Face Technologies for repair.

Comments:____
____
____

LTPP Dipstick Data Collection Form Dipstick Field Activity Report Transverse Profile Form DS-8	State Code [_ _] LTPP Section ID [_ _ _ _] Date (dd/mmm/yy) [_ _/_ _ _ /__]

Operator: ________________________ Employer: ______________________

Recorder: ________________________ Employer: ______________________

Dipstick Serial Number: ___________

Pre-Operational Checks Performed: _____

Start Time (military): _____________ Stop Time (military): _____________

Weather: ____

Traffic Control Crew: ______________________________
____
____

Other Personnel at Site: ______________________________
____

Dipstick Data Collection Form
Transverse Profile
Form DS-9

LTPP Code [_ _]
LTPP Section [_ _ _ _]
Date (dd/mmm/yy) _ _/_ _ _/_ _

OPERATOR:____________ RECORDER: ____________ DIPSTICK SERIAL NO: ____________

Location	DIPSTICK READING																Total	Closure
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		
0 m																		
15.25 m																		
30.50 m																		
45.75 m																		
61.00 m																		
76.25 m																		
91.50 m																		
106.75 m																		
122.00 m																		
137.50 m																		
152.40 m																		

LTPP Dipstick Operatiions
LTPP Major Maintenance/Repair Activity Report
Form DS-10

Region: ________________________________ Date: ______________________________

Make: Face Construction Technology **Model:** ___________________

Serial Number: ________________

Reason for Maintenance Work (Choose only one)

Scheduled: _________ Not Scheduled: _________

Description Of Maintenance And Reason: ____

____

____

____

____

Agency Performing Maintenance: **Cost: ________________**

Name: ____

Street: ____

City: _________________________________ State: __________ Zip: ___________

Phone Number: ____

Contact Name: ____

Date In: ____

Date Out: ____

APPENDIX III

DATA COLLECTION FORM FOR ROD AND LEVEL PROFILE MEASUREMENTS

LTPP Rod and Level Data Collection Form Longitudinal Profile Measurements Form RL-1

LTPP Code	[_ _]
LTPP Section	[_ _ _ _]
Date (dd/mmm/yy)	_ _/_ _ _/ _ _

Reading Number	I.S.	B.S.	F.S.	Reading Number	I.S.	B.S.	F.S.	Reading Number	I.S.	B.S.	F.S.
Stn 0+00				34				68			
1				35				69			
2				36				70			
3				37				71			
4				38				72			
5				39				73			
6				40				74			
7				41				75			
8				42				76			
9				43				77			
10				44				78			
11				45				79			
12				46				80			
13				47				81			
14				48				82			
15				49				83			
16				50				84			
17				51				85			
18				52				86			
19				53				87			
20				54				88			
21				55				89			
22				56				90			
23				57				91			
24				58				92			
25				59				93			
26				60				94			
27				61				95			
28				62				96			
29				63				97			
30				64				98			
31				65				99			
32				66				100			
33				67							

, B.S. = Back Sight, F.S. = Foresigh

Comments:

LTPP Rod and Level Data Collection Form Longitudinal Profile Measurements Form RL-2

LTPP Code	[_ _]
LTPP Section	[_ _ _ _]
Date (dd/mmm/yy)	_ _ /_ _ _ / _ _

Reading Number	I.S.	B.S.	F.S.	Reading Number	I.S.	B.S.	F.S.	Reading Number	I.S.	B.S.	F.S.
101				135				169			
102				136				170			
103				137				171			
104				138				172			
105				139				173			
106				140				174			
107				141				175			
108				142				176			
109				143				177			
110				144				178			
111				145				179			
112				146				180			
113				147				181			
114				148				182			
115				149				183			
116				150				184			
117				151				185			
118				152				186			
119				153				187			
120				154				188			
121				155				189			
122				156				190			
123				157				191			
124				158				192			
125				159				193			
126				160				194			
127				161				195			
128				162				196			
129				163				197			
130				164				198			
131				165				199			
132				166				200			
133				167							
134				168							

, B.S. = Back Sight, F.S. = Foresigh

Comments: ____________________

____

LTPP Rod and Level Data Collection Form
Longitudinal Profile Measurements
Form RL-3

LTPP Code [_ _]
LTPP Section [_ _ _ _]
Date (dd/mmm/yy) _ _ /_ _ _ / _ _

Reading Number	I.S.	B.S.	F.S.	Reading Number	I.S.	B.S.	F.S.	Reading Number	I.S.	B.S.	F.S.
201				235				269			
202				236				270			
203				237				271			
204				238				272			
205				239				273			
206				240				274			
207				241				275			
208				242				276			
209				243				277			
210				244				278			
211				245				279			
212				246				280			
213				247				281			
214				248				282			
215				249				283			
216				250				284			
217				251				285			
218				252				286			
219				253				287			
220				254				288			
221				255				289			
222				256				290			
223				257				291			
224				258				292			
225				259				293			
226				260				294			
227				261				295			
228				262				296			
229				263				297			
230				264				298			
231				265				299			
232				266				300			
233				267							
234				268							

, B.S. = Back Sight, F.S. = Foresigh

Comments:

LTPP Rod and Level Data Collection Form Longitudinal Profile Measurements Form RL-4	LTPP Code [_ _] LTPP Section [_ _ _ _] Date (dd/mmm/yy) _ _ /_ _ _ / _ _

Reading Number	I.S.	B.S.	F.S.	Reading Number	I.S.	B.S.	F.S.	Reading Number	I.S.	B.S.	F.S.
301				335				369			
302				336				370			
303				337				371			
304				338				372			
305				339				373			
306				340				374			
307				341				375			
308				342				376			
309				343				377			
310				344				378			
311				345				379			
312				346				380			
313				347				381			
314				348				382			
315				349				383			
316				350				384			
317				351				385			
318				352				386			
319				353				387			
320				354				388			
321				355				389			
322				356				390			
323				357				391			
324				358				392			
325				359				393			
326				360				394			
327				361				395			
328				362				396			
329				363				397			
330				364				398			
331				365				399			
332				366				400			
333				367							
334				368							

, B.S. = Back Sight, F.S. = Foresigh

Comments:

LTPP Rod and Level Data Collection Form Longitudinal Profile Measurements Form RL-5

LTPP Code	[_ _]
LTPP Section	[_ _ _ _]
Date (dd/mmm/yy)	_ _ /_ _ _ / _ _

Reading Number	I.S.	B.S.	F.S.	Reading Number	I.S.	B.S.	F.S.	Reading Number	I.S.	B.S.	F.S.
401				437				473			
402				438				474			
403				439				475			
404				440				476			
405				441				477			
406				442				478			
407				443				479			
408				444				480			
409				445				481			
410				446				482			
411				447				483			
412				448				484			
413				449				485			
414				450				486			
415				451				487			
416				452				488			
417				453				489			
418				454				490			
419				455				491			
420				456				492			
421				457				493			
422				458				494			
423				459				495			
424				460				496			
425				461				497			
426				462				498			
427				463				499			
428				464				500			
429				465				501			
430				466				502			
431				467				503			
432				468				504			
433				469				505			
434				470				506			
435				471				507			
436				472				508			

B.S. = Back Sight, F.S. = Foresigh

Comments:

APPENDIX IV

FREQUENCY OF DATA COLLECTION AT TEST SECTIONS

LONG TERM PAVEMENT PERFORMANCE

PROGRAM DIRECTIVE

Directive Number: PROF-1

Supersedes: SHRP Directive P-1

Date: September 1, 1994

Subject: Profile Monitoring Frequency and Priorities

This directive documents the nominal profile measurement frequency for all Long-Term Pavement Performance (LTPP) test sections and the priorities to be considered when all required measurements cannot be completed.

A. Measurement Frequency

1. The nominal frequency for routine profile measurement of LTPP test sections shall be as follows. Where a given test section is included in more than one of the categories outlined, the maximum measurement frequency applies.

LTPP Experiment/Program	Nominal Measurement Frequency	Remarks
GPS	Biannual	Approximately 1/2 of all test sections to be tested in any one year
SPS	Biannual	See 2 and 3 below
Seasonal Monitoring - sites which freeze	5 times/year every other year	Twice during winter season, once per season otherwise
Seasonal Monitoring - sites which do not freeze	4 times/year every other year	Once per season
WIM locations	At time of calibration	Additional measurements will be conducted on selected sites at varying frequencies

2. Pre-construction measurement for SPS-3, -4, -5, -6 and -7 projects and post-construction measurement for all SPS projects is to be conducted within three months of construction. Where this is not feasible, measurement up to six months prior to (in the case of pre-construction measurement) or after (in the case of post-construction measurement) actual construction will suffice.

3. Measurement of Sections 2, 4, 8, and 10 in SPS-1 projects and Sections 1, 5, 8, and 12 in SPS-2 projects (hereafter referred to as "weak" sections) is to be conducted every six months. Where this is not feasible, measurement intervals up to once per year will suffice.

4. Pre-construction or terminal measurement is to be conducted on any section which is to be modified (overlaid, reconstructed, etc.), whether it will continue as an LTPP test section or not. Where feasible, measurement should be conducted not more than three months prior to construction. Where this is not feasible, measurement up to six months prior to actual construction will suffice.

B. Priorities

Where resource limitations prohibit completion of all planned profile measurements, the following order of precedence shall be followed in setting priorities.

Priority Level	Type of Measurement	Remarks
1	Pre-construction measurement for SPS-3, -4, -5, -6 and -7 experiments	
1	Post-construction measurement for SPS-1, -2, -5, -6 and -7 experiments	Measurement may be postponed if absolutely necessary, but must be completed within six months of the specified time.
1	Pre-construction or terminal measurement for any section (GPS or SPS) which is to be modified	
1	Seasonal monitoring of sites which have been instrumented	Surveying of seasonal monitoring sites which have not been instrumented is not required.
2	Measurement of "weak" SPS-1 or -2 sections	Measurement may be postponed if absolutely necessary, but must be completed within six months of the specified time.
2	Long term measurement of GPS and SPS sites	Measurement may be postponed up to one year.
3	WIM locations	Measurement may be postponed up to one year.

APPENDIX V

PROCEDURE FOR REPLACING A SENSOR IN THE WHEEL PATH WITH THE CENTER SENSOR IN K.J. LAW PROFILOMETER[â]

NOT COMPLETED

APPENDIX VI

PROFILE TROUBLE SHOOTING GUIDE

APPENDIX VI

PROFILE TROUBLE SHOOTING GUIDE

This appendix contains a catalog of problems commonly encountered by LTPP operators when collecting and reviewing profile data. Knowledge of these problems will help operators to collect more accurate and valid profile data for the LTPP program. These commonly encountered problems can be grouped into the following four categories:

1. Spikes in Profile due to Equipment Problems
2. Miscalibrated DMI
3. Early Start of Data Collection.
4. Different Profiles.

A brief description of each of these problem groups is provided next along with typical plots illustrating such conditions.

To detect most of these problems, the profile data in question must be compared to those collected during the previous site visit (see Section 2.2.5.2). This requires that profile data from the previous site visit be available on the computer hard drive. Furthermore, in order to perform an accurate and valid comparison, profile data from the previous site visit must be error free. Descriptions and references made later in this appendix to the profile data comparisons assume that data from the previous site visit are error free.

1. Spikes in Profile Due to Equipment Problems

Spikes can be introduced in the profile data as a result of equipment problems. These spikes can be identified by comparing multiple profile runs at a section. Accordingly, once a set of profile runs has been collected, the operator should compare the data from the repeat runs using the multi-run plot option in PROQUAL (see Section 3.3.5 of PROQUAL Manual). This comparison should be performed separately for the left, right and center wheel path profile data. Figure VI-1 illustrates the presence of a spike in the profile data. This figure shows five profile runs collected on the left wheel path. The profile data for run 4 indicates a spike that is not present in the other four runs. Profile data for run 4 has been offset in figure for clarity; in the PROQUAL multi-run plot option, these repeat profile runs are color-coded (i.e., different color for each run). Since the spike only occurs in one run of the data set, it is highly unlikely that it is caused by a pavement feature. When such condition is encountered, the operator should determine if the spike is due to an equipment problem or if it is a pavement feature.

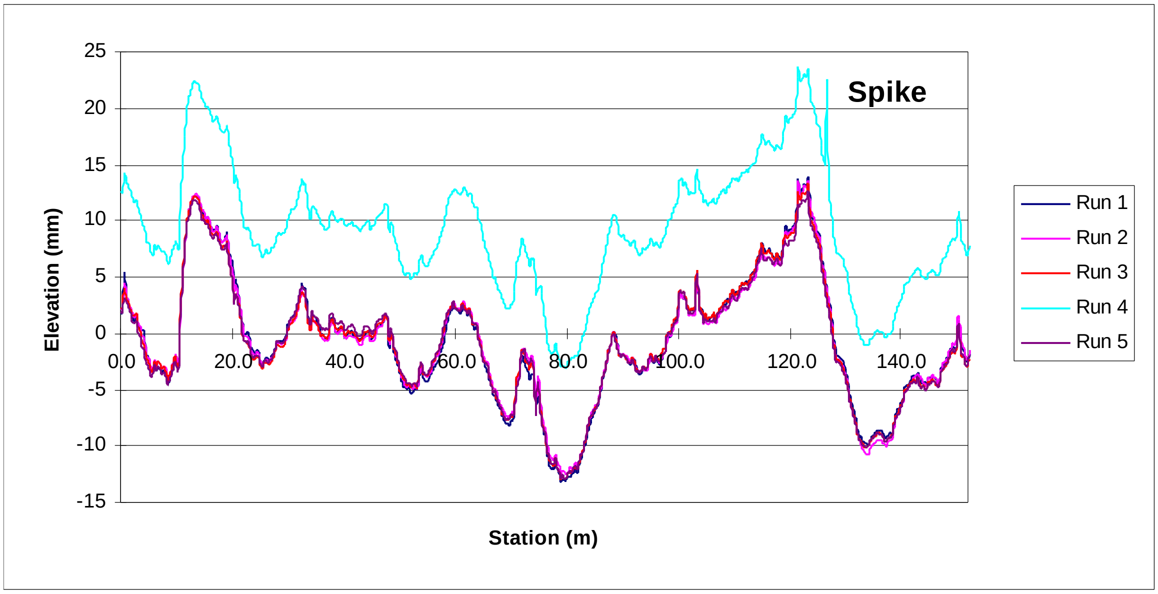

Figure VI-1. Spike in profile data (profile data for run 4 has been offset for clarity).

2. Miscalibrated Distance Measuring Instrument (DMI)

A miscalibrated DMI cannot be detected by comparing the five repeat profile runs obtained during a site visit. However, when those runs are compared with the profile runs collected during the previous site visit, the profile (elevation versus station) plot for the more recently collected data will appear squeezed or stretched in the x (station) direction if the vehicle has a miscalibrated DMI. The comparison of the current and the previous profile data should be carried out using the multi-year plot option in PROQUAL (see Section 3.3.6 of PROQUAL Manual). An example of profile data associated with a miscalibrated DMI is shown in Figure VI-2; data for May 2, 1990 was collected using a miscalibrated DMI.

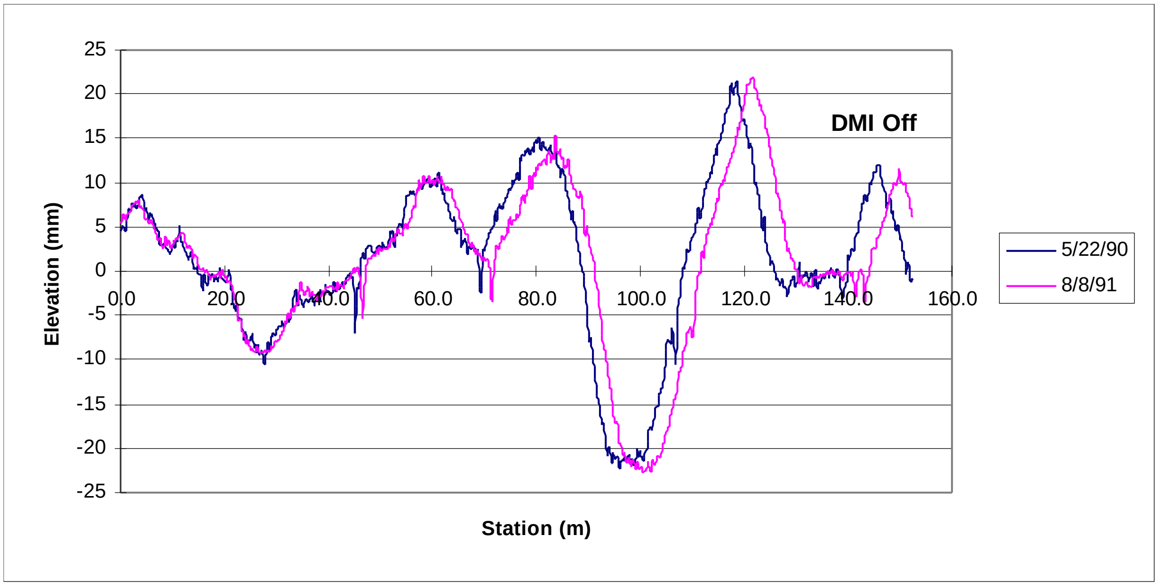

Figure VI-1. Data collecetd with a correctly calibrated and a miscalibrated DMI.

When this problem is encountered, operator should check tire pressure of vehicle to ensure it is within the recommended values given in Section 3.3.5.2 of the LTPP Profile Manual. If the tire pressure is outside those limits, operator should adjust tire pressure and obtain a new set of measurements at the section. If the difference in the distance between the current data and previous data at the end of the section is less than or equal to 0.5 m for a GPS section, the current data set is considered to be acceptable. If the differences in the distances between the current visit and the previous visit is greater than 0.5 m, the operator should determine if the difference is occurring because the DMI is incorrect during the current visit or if it was incorrect during the previous visit. The following procedures can be used by the operator to make this determination.

1.The operator can determine if the DMI is calibrated correctly by running the section specifying the ‘photocell start’ and ‘photocell end’ method. The Stop Record Method (see Section 2.3.5.5) should be set to ‘photocell’ in order profile the section using this procedure. If the length of the section obtained when the section is profiled using this procedure is within ± 0.3 m of 152.4 m, the DMI can be assumed to be working properly. However, there may be cases where the actual length of the site is not 152.4 m. So if the distance obtained using the described procedure is outside the specified limit, it cannot be concluded that the DMI is working incorrectly. If such a case is encountered the operator should follow the procedure described in the next step.

2. Currently it is expected that all test sections would have been visited at least twice by the T-6600 profiler. The operator can check on the accuracy of the DMI for the previous visit by calling the office and asking the office personnel to compare the previous year data with other data that is available for the site, that has been collected with the T-6600 profiler. The purpose of this comparison is to determine if there is any error in DMI associated with the data from the previous visit. The office personnel should compare the relative position of the profile at the end of the section for all previous visits to the section by the T-6600 profiler, and convey that information to the operator. The office personnel together with operator can then use the available information to judge the accuracy of the DMI for the current data. If all the available data indicates that the DMI for the previous visit is accurate, the indications are that the DMI in the unit is out of calibration. The operator should proceed to another site, and compare the profile plots following the procedures described previously. If the data at that site also indicates the DMI is out of calibration, the DMI should be calibrated before further profile data is collected.

For SPS sites differences between runs can occur because of wheel path wander. This effect will usually be more pronounced in the sections that are located towards the end of the SPS section. When comparing profile data between two years at a SPS section, close attention should be paid to the first two sections in a SPS site. If the profile for the current data and the previous years data satisfies the criteria that were described previously at the first two sites, it can be concluded that the DMI is functioning correctly for the current visit. In such a case, a difference in distance of up to 1 m can be considered to be acceptable for the other sections in the SPS site.

3. Early Start of Data Collection

An early profile start can occur when the photocell triggers data collection prior to the start of the test section. It is possible for all repeat profile runs during a site visit to have the same starting location, but all are early starts. This problem can occur if there is a mark on the pavement that triggers data collection to start at the same location, but this location is before the beginning of the test section. When the current profile data are compared with those collected during the previous site visit, the early start problem can be easily identified by a clear shift in the two profile data sets. This profile comparison should be carried out using the multi-year plot option of PROQUAL (see Section 3.3.6 of PROQUAL Manual). The early start problem is illustrated in Figure VI-3, which shows the profile plot for a single run along the left wheel path conducted on three different dates -- April 8, 1990; October 18, 1990; and August 10, 1994. The profile plot for the last two dates have similar start locations, but that for the earlier date (April 8, 1990) is shifted to the left because of an early start. If the early start problem is caused by a mark on the pavement that is located prior to the pavement section, the operator can use the horizontal photocell to initiate data collection.

The early start problem can also occur in one or more runs within a profile data set collected during a single site visit. This problem can be easily identified by comparing the repeat profiler runs using the multi-run plot option in PROQUAL; one or more of runs will be shifted to left of the others if there is an early start. Although a plot illustrating the early start problem within a set of repeat runs is not included in this appendix, that plot is very similar to that shown in Figure VI-

3. If an early start is detected in one or more profile runs, the operator should perform additional profile runs until a set of error free data (meeting the criteria described in Section 2.2.5 of the LTPP Profile Manual) is obtained. Again, if the early start problem is caused by a mark on the pavement that is located prior to the pavement section, the operator can use the horizontal photocell to initiate data collection.

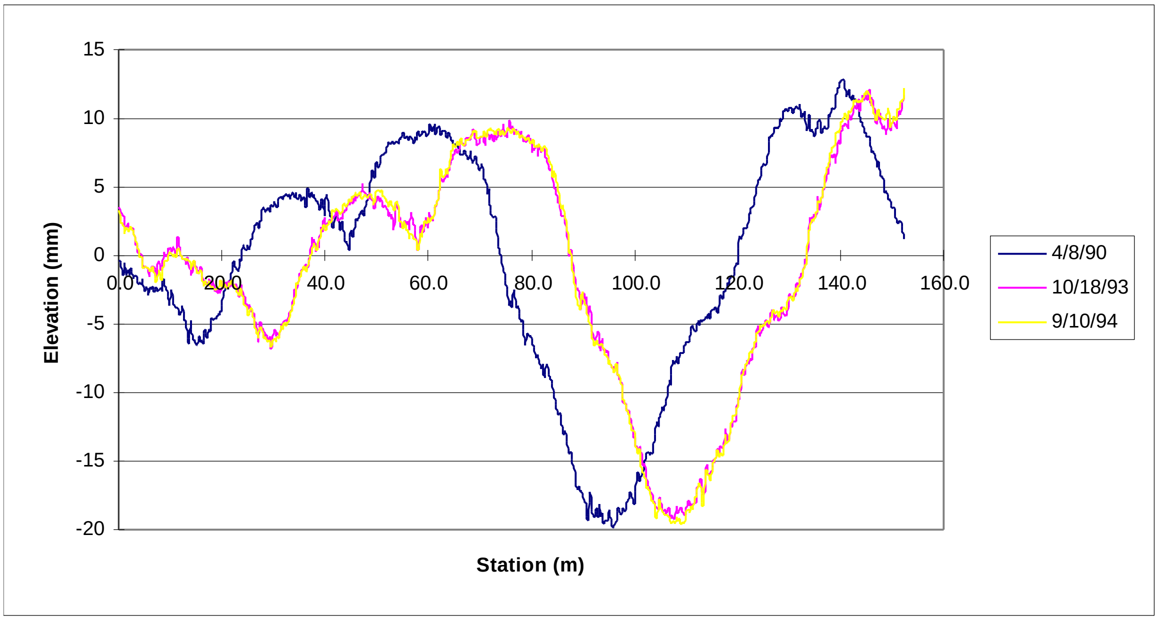

Figure VI-3. Example of early profile start.

4. Different Profiles

The term “different profiles” is used to describe the occurrence of the following condition:

> When operator compares repeat profile runs collected during single site visit, no problems are observed in the data (i.e., error free)

AND

> When operator compares current data with that from previous site visit (also error free), the two sets of profiles appear to be different.

Such condition can be caused by the application of rehabilitation or maintenance activities to the sections between profiler site visits. It can also occur when the location of test section is incorrectly selected during one of the site visits.

Figure VI-4 illustrates the case where rehabilitation has been performed on a test section between site visits. This figure shows a plot of the left wheel path profile obtained on two separate site visits -- September 10, 1991 and October 4, 1994. As can be observed, the two profiles are completely different. In this particular example, the profile differences were caused by placement of an overlay on the section some time between the two site visits. Figure VI-4 can also be used to illustrate the case where the location of the test section has been incorrectly selected during one of the site visits; similar differences are seen in such a plot.

If a case such as that shown in Figure VI-4 is encountered, the operator should first verify that the test section location is correct. If such condition is encountered at a SPS section or at a GPS section that was profiled in conjunction with a SPS section, the operator should verify that the stationing used for subsectioning is correct. If evidence of rehabilitation is noted at the section, it should be entered as an Operator Comment and also noted in the LTPP Profilometer Field Activity Report.

An example of the case where maintenance has occurred at a test section between site visits is illustrated in Figure VI-5. This figure shows a plot of the left wheel path profile obtained on two separate site visits -- August 8, 1991 and August 5, 1992. As can be observed, the beginning of the profile for the two site visits are different indicating possible maintenance at the test section. If a case such as that shown in Figure VI-5 is encountered, the operator should look to see if there is evidence of maintenance activities such as patching within the test section. If evidence is found, the operator should indicate that maintenance has been performed on the test section in the Operator Comment Field (Suggested comment: Possible maintenance in section) and also note it in the LTPP Profilometer Field Activity Report.

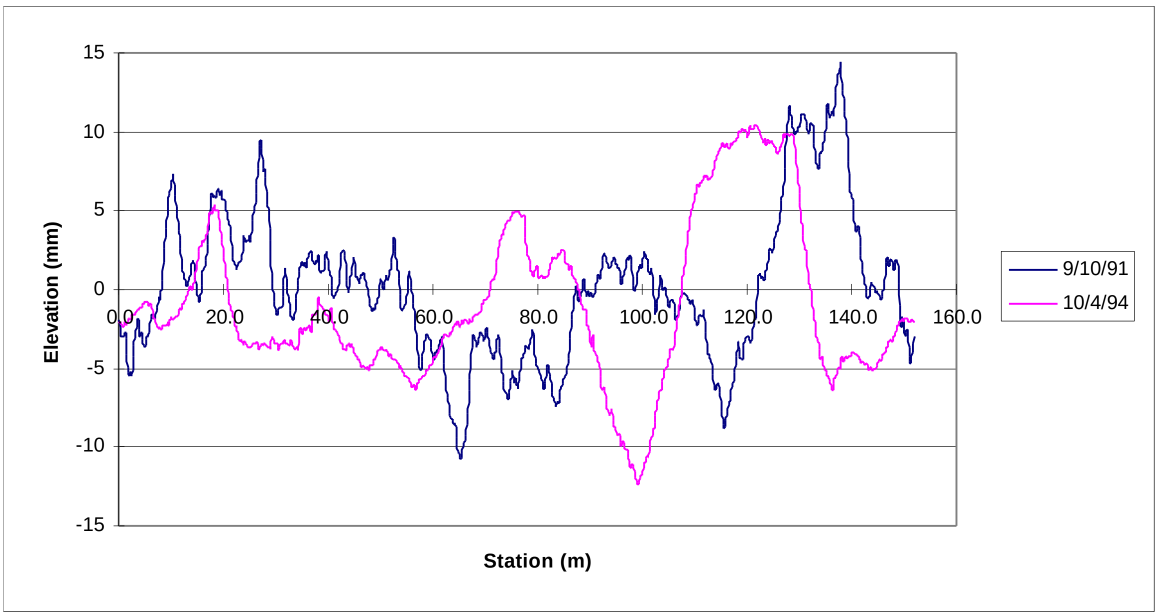

Figure VI-4. Differences in profile due to rehabilitation of section.

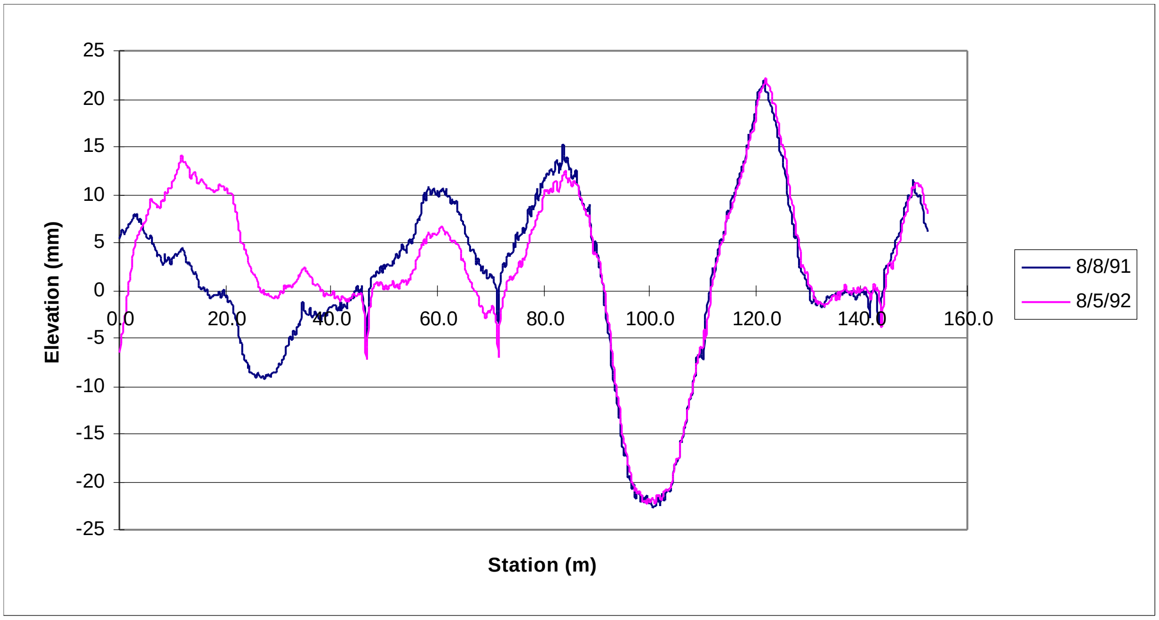

Figure VI-5. Differences in profile due to maintenance of section.